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Nevada Test Site

Routine Radiological Environmental Monitoring Plan

December 1998

Prepared for:
U.S. Department of Energy
Nevada Operations Office

Prepared by:
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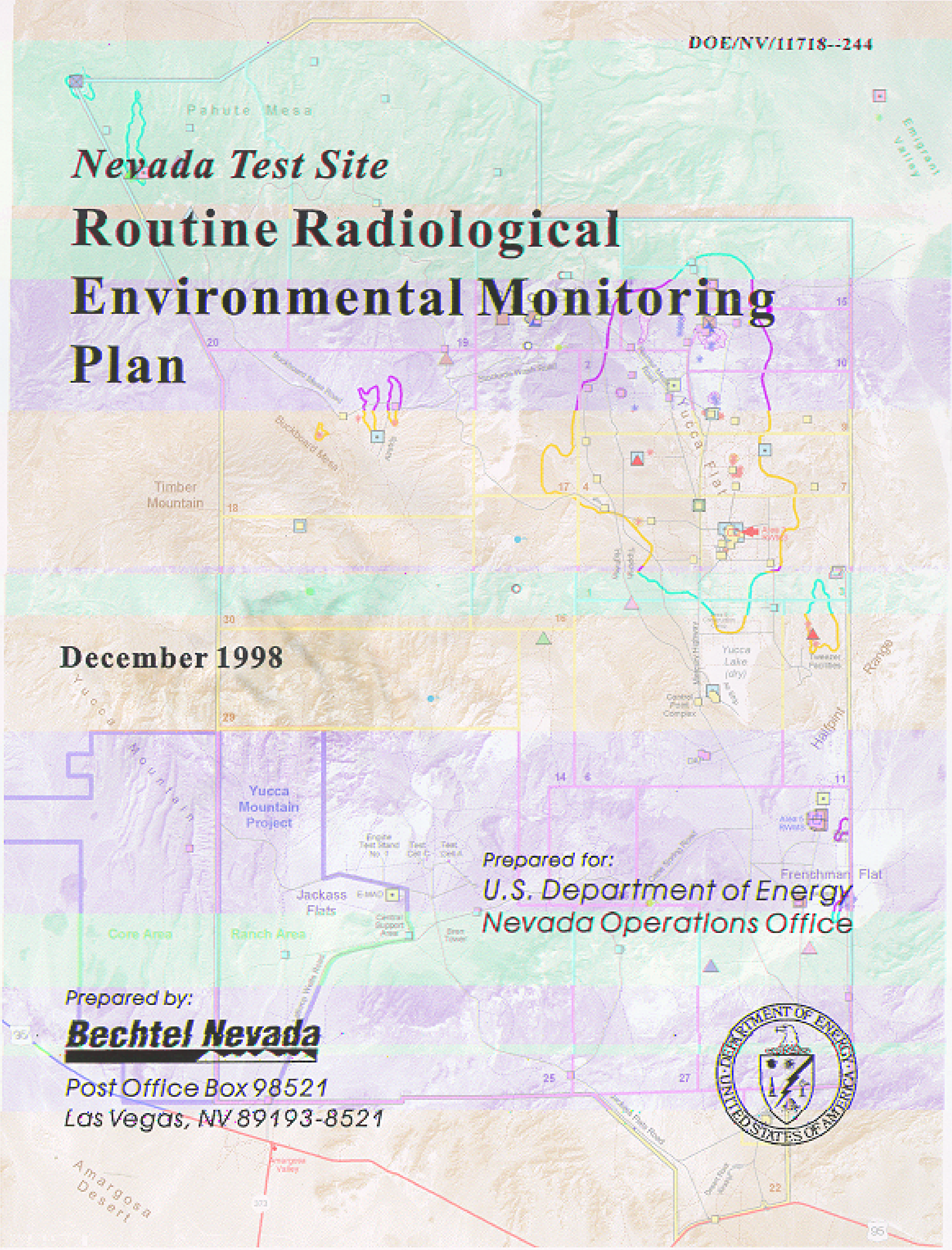

DISCLAIMER

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Work Performed Under Contract No. DE-AC08-96NV11718

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ACRONYMS and ABBREVIATIONS

ANSI	American National Standards Institute
ASER	Annual Site Environmental Report
BN	Bechtel Nevada
CAS	Corrective Action Site
CAU	Corrective Action Unit
COC	Constituent of Concern
CTLP	Community Technical Liaison Program
DCG	Derived Concentration Level
DOE	U.S. Department of Energy
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DQO	Data Quality Objective
DRI	Desert Research Institute
DoD	U.S. Department of Defense
DTRA	Defense Threat Reduction Agency
EDE	Effective Dose Equivalent
EIS	Environmental Impact Statement
EM	Environmental Monitoring
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
ERDA	Energy Research and Development Administration
ES&H	Environment, Safety, and Health
FAM	Facility Area Monitoring
FFACO	Federal Facility Agreement and Consent Order
GCD	Greater Confinement Disposal
GIS	Geographic Information System
GZ	Ground Zero
HTO	Tritiated Water
IT	International Technologies Corp.
LANL	Los Alamos National Laboratory
LLW	Low-Level Waste
LLWMU	Low-Level Waste Management Unit
LTHMP	Long-Term Hydrologic Monitoring Program
MA	Million Years
MEI	Maximally Exposed Individual
MDC	Minimum Detectable Concentration
NAFR	Nellis Air Force Range
NDEP	Nevada Department of Environmental Protection
NLVF	North Las Vegas Facility
NTS	Nevada Test Site
QAASP	Quality Assurance, Analysis, and Sampling Plan
RCRA	Resource Conservation and Recovery Act
RCT	Radiological Control Technician
RIDP	Radionuclide Inventory and Distribution Program
RREMP	Routine Radiological Environmental Monitoring Program

ACRONYMS and ABBREVIATIONS

RWMS	Radioactive Waste Management Site
SAP	Sampling and Analysis Plan
SDWA	Safe Drinking Water Act
STL	Special Technologies Laboratory
TEND	Track-Etch Neutron Dosimeter
TTR	Tonopah Test Range
UGTA	Underground Test Area
WAMO	Washington Aerial Measurements Operations
WEF	Waste Examination Facility
WM	Waste Management
WMD	Waste Management Division

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1.0 INTRODUCTION

The U.S. Department of Energy (DOE) manages the Nevada Test Site (NTS) in a manner that meets evolving DOE missions and responds to the concerns of affected and interested individuals and agencies. This Routine Radiological Environmental Monitoring Plan (RREMP) addresses compliance with DOE Orders 5400.1 and 5400.5 and other drivers requiring routine effluent monitoring and environmental surveillance on the NTS. This monitoring plan, prepared in 1998, addresses the activities conducted onsite NTS under the Final Environmental Impact Statement and Record of Decision (EIS) (1996a). This radiological monitoring plan, prepared on behalf of the NTS landlord, brings together sitewide environmental surveillance; site-specific effluent monitoring; and operational monitoring conducted by various missions, programs, and projects on the NTS. The plan provides an approach to identifying and conducting routine radiological monitoring at the NTS, based on integrated technical, scientific, and regulatory compliance data needs.

This plan identifies the requirements for radiologic monitoring on and off the NTS and at associated facilities under Necessary and Sufficient Standards identified in 1997, including DOE Orders, state and federal regulations, and stakeholder issues. The monitoring plan focuses on the need to ensure that the public and the environment are protected, that compliance with the letter and the spirit of the law is achieved, and that good land stewardship is practiced. The monitoring plan uses a decision-based approach to identify the environmental data that must be collected and provides Quality Assurance, Analysis, and Sampling Plans (QAASPs) which ensure that defensible data is generated. The approach is based on a modification of the U.S. Environmental Protection Agency's (EPA) Data Quality Objective (DQO) process, a seven-step process that calls for identification of the decisions that data collection activities must support, and uses a logical structure to develop the plan for data collection and analysis. The plan provides one central, integrated approach for routine radiological monitoring, sitewide, on and off the NTS and also at associated DOE facilities including the North Las Vegas Facility (NLVF), the Remote Sensing Laboratory, the Special Technologies Laboratory (STL), Los Alamos Operations, and Washington Aerial Measurements Operations (WAMO).

The plan is organized into seven sections, including this introduction, a description of the site conceptual model and sources of radiation with the potential to affect public health and the environment at the NTS, drivers requiring routine radiological environmental monitoring, a summary description of integrated plans to monitor the five media in the environment onsite and offsite (air, water, soils, plants, and animals), a description of operational monitoring requirements, a summary of a conceptual plan for data management, and a description of how this plan relates to other environmental monitoring activities on the NTS. In the appendices, detailed QAASPs for air, water, and biota monitoring are presented. A subsequent appendix summarizes the DQO process used for each of the five media. The last appendix presents a checklist for use in developing vadose zone monitoring Sampling and Analysis Plans (SAPs). As discussed in both the Plan and the DQO Appendix, detailed SAPs for vadose zone monitoring must address site-specific issues and are the responsibility of specific projects within the Waste Management and Environmental Restoration Divisions of DOE/Nevada Operations Office (NV).

The plan has been prepared by a team of scientists from DOE/NV, Bechtel Nevada (BN), International Technology Corp. (IT), Desert Research Institute (DRI), and the Joint Testing Organization. The team brought together health physicists, geologists, hydrogeologists, soil scientists, biologists, chemists, statisticians, and managers of NTS operations who, in a series of workshops, used a consensus-based approach to developing the details of DQOs for each media and, in the process, integrated information from all disciplines into the decision-making process for each specific medium. After the team agreed upon DQOs of the monitoring program, BN prepared the sampling and analysis approach for each media.

This RREMP will be reviewed annually and updated biannually as required.

2.0 SITE CONCEPTUAL MODEL AND SOURCES OF RADIATION

2.1 SITE CHARACTERISTICS

2.1.1 GEOGRAPHY AND LAND USE

Geography

The NTS and surrounding communities lie within the Basin and Range Physiographic Province. This province is characterized by long, linear, generally north-south trending mountain ranges separated by closed, down-dropped valleys. The Great Basin hydrographic basin generally coincides with the northern Basin and Range Physiographic Province. The Great Basin hydrographic basin is defined through internal drainage; no streams or rivers have a pathway out of the basin.

Regional geology controls the topography of the NTS. Topography of the eastern and southern part of the NTS is characterized by block-faulted basins bounded by mountain ranges. Topography of the northwestern part of the NTS is dominated by the volcanic highlands of Pahute and Rainier Mesas (Figure 2.1). The primary valleys on the NTS are Yucca Flat, Frenchman Flat, and Jackass Flats. Yucca and Frenchman Flats are hydrologically closed; each contains playas. Jackass Flats drains westward off the NTS through Fortymile Canyon. Pahute Mesa drains off the NTS to Gold Flat and Oasis Valley. Elevations at the NTS range from less than 1,000 meters (m) (3,280 feet [ft]) in Frenchman and Jackass Flats to about 2,340 m (7,675 ft) on Rainier Mesa and about 2,200 m (7,216 ft) on Pahute Mesa. Natural topography has been altered by anthropogenic structures including roads, pads, flood control structures, various excavations, and test activities.

Land Use

Native Americans were the first to use the lands now within the NTS. The Shoshone lived at springs and playas over the northern NTS. Springs on the southern NTS were used by the Southern Paiutes. Early settlers established several cattle ranching and wild horse capture operations at local springs, including Cane Spring on the western margin of Frenchman Flat. Small mining operations have existed on the NTS in the Oak Spring District and the Mine Mountain District (Reno and Pippin, 1985). The mining camp of Wahmonie had a population of 1,500 in 1928 (Allred *et al*., 1963). Today, ranching and mining remain important land uses in southern Nevada. Recreational activities and irrigation-based agriculture have recently become important land uses in surrounding areas. Las Vegas' favorable economic conditions have spurred rapid development in Clark County. Neighboring Nye County, where the NTS is located, has also developed recently as a suburban community to Las Vegas.

The NTS was withdrawn from all forms of appropriation under public land laws in 1940. The U.S. Bureau of Land Management has recommended reviewing the land withdrawal in 100 years. Current land use at the NTS is described in the NTS EIS (DOE, 1996a). Current land use recognizes the contaminated nature of selected areas of the NTS and establishes land use zones on the NTS which include (1) a nuclear test zone, (2) a nuclear and high-explosive test zone, (3) a radioactive waste management zone, (4) a Yucca Mountain site characterization zone, (5) a solar enterprise zone, (6) a reserved zone, and (7) a defense industrial zone. All current land uses restrict uncontrolled public access to the NTS.

2.1.2 METEOROLOGY AND CLIMATE

The climate at the NTS is characterized by limited precipitation, low humidity, and large diurnal temperature ranges. The lower elevations are characterized by hot summers and mild winters, typical of the Great Basin. As elevation increases, precipitation increases and temperatures decrease.

Annual precipitation at higher NTS elevations is about 23 centimeters (cm) (9 inches [in]), which includes snow accumulations. The lower elevations receive approximately 15 cm (6 in) of precipitation annually, with occasional snow accumulations lasting only a few days (Quiring, 1968). The NTS lies in the rain shadow of the Sierra Nevada. There, clouds carried by prevailing winter winds lose much of their moisture before descending from the mountains (Humphrey, 1962). Winter rains, carried by eastward-moving polar Pacific air, are effectively blocked much of the time. Accordingly, the continental polar air mass often dominates the winter climate. In summer, precipitation originates from sporadic invasions of moisture-laden air from the Gulf of Mexico, resulting in isolated showers with large variations among local precipitation amounts.

Average daily minimum and maximum temperatures on the NTS range from as low as -11 C (Centigrade) (12 F [Fahrenheit]) in January to 43 C (109 F) in July, respectively (DOE, 1996a), depending on location and elevation (Table 2.1). The annual average temperature in the NTS area is 19 C (66 F) (National Oceanic and Atmospheric Administration [NOAA], 1991). Monthly average temperatures range from 7 C (44 F) in January to 32 C (90 F) in July. Relative humidity readings (taken four times per day) range from 11 percent in June to 55 percent in January and December (DOE, 1996a).

Average annual wind direction varies with location (Figure 2.2). The prevailing wind direction during the winter months is north-northeasterly, and during the summer months winds are southerly. At high elevations on Pahute Mesa, the average annual wind speed is 16 kilometers/hr (kph) (10 miles/hr [mph]). In the Yucca Flat basin, the average annual wind speed is 11 kph (7 mph). At Mercury, the average annual wind speed is 13 kph (8 mph). Wind speeds in excess of 97 kph (60 mph), with gusts up to 172 kph (107 mph), may be expected to occur once every 100 years (Quiring, 1968).

Additional severe weather in the region includes occasional thunderstorms, lightning, tornados, and sandstorms. Severe thunderstorms may produce high precipitation that continues for approximately one hour and may create a potential for flash flooding (Bowen and Egami, 1983). Few tornados have been observed in the region and are not considered a significant event. The estimated probability of a tornado striking a point at the NTS is extremely low (3 in 10 million years) (Ramsdell and Andrews, 1986).

2.1.3 ECOLOGY

Plants

The following descriptions of vegetation were taken from the NTS EIS (DOE, 1996a). The vegetation of the NTS falls in two broad classifications: Mojave Desert and Great Basin Desert plant communities. Mojave Desert plant communities are found at elevations below approximately 1,219 m (4,000 ft) on the alluvial fans and valley bottoms of Jackass Flats, Rock Valley, and Mercury Valley; and on the alluvial fans of Frenchman Flat. Creosote bush is the visually dominant shrub, and it is associated with a variety of other shrubs, depending on soil type and elevation. Shadscale is codominant with creosote bush on most alluvial fans where desert pavement is well defined. On deep, loose soil, such as that which exists on southern Jackass Flats and northeastern Frenchman Flat, creosote bush is codominant with white bursage.

Plant communities typical of the desert that lie in the Great Basin occur at elevations generally above 1,524 m (5,000 ft) in the northern third of the NTS and in Area 13. Most of the basin 5-0.ties typTD v/,s. Shadshrub, ollheafand it lsolant vatiod. On deep, loose sccurmiddlewith 1

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wsTiesephpagen,ctroducefoetpisoil,suchtypTtwomshrcheatgtJac,Rudubson of the bird species on the NTS are transients. Over 1,000 species of arthropods have been identified on the NTS, but this probably represents a small fraction of the arthropod species present. About 80 percent of these species are insects; ants, termites, and darkling beetles are the most common insect taxa.

Many animal species on the NTS are common only in the Mojave Desert habitats to the south or in the Great Basin Desert habitats to the north. Typical Mojave Desert species found on the NTS include kit fox, Merriam's kangaroo rat, desert tortoise, chuckwalla, western shovelnose snake, and sidewinder snake. Typical Great Basin species in this region include cliff chipmunk, Great Basin pocket mouse, mule deer, northern flicker, scrub jay, Brewer's sparrow, western fence lizard, and striped whipsnake. About 60 wild horses live on the northern part of the NTS, usually on or near Rainier Mesa.

Many of the birds on the NTS use natural and man-made water sources which include 20 known springs or seeps (Hansen *et al*., 1997), and over 20 man-made impoundments such as sumps and sewage lagoons. Bats often seek food over these water sources, and the distribution of the wild horses on the NTS may be related to the location of man-made ponds. Occasionally, migratory shorebirds and waterfowl have been observed on the playas in Yucca and Frenchman flats when surface runoff periodically ponds on the playas.

Several species of state-designated game animals occur in this region, including 1,500 to 2,000 mule deer and an unknown number of mountain lions, desert and Nuttall's cottontails, chukar, Gambel's quail, mourning dove, and several species of waterfowl. Bighorn sheep and pronghorns inhabit surrounding areas and may on occasion stray onto the NTS. Bobcats and kit foxes are the only state-designated fur-bearing animals on the NTS. Bighorn sheep are hunted on the Nellis Air Force Range (NAFR). No other hunting or trapping is allowed on the NTS or the NAFR Complex.

2.1.4 REGIONAL GEOLOGY

Mountains of the Basin and Range Physiographic Province are composed of primarily Proterozoic and Paleozoic sedimentary rocks. These rocks are largely of marine origin, made of carbonates, shales, sandstones, and conglomerates (Stewart, 1978; 1980). These sedimentary rocks were folded and faulted during multiple periods of deformation. In the western part of the Basin and Range Province, these sedimentary rocks were intruded by granitic rocks of the Mesozoic age (Stewart, 1978; 1980). The Proterozoic and Paleozoic sedimentary rocks and the Mesozoic intrusions underwent erosion during the early Cenozoic Era. This period of erosion was followed by extensional faulting of the older rocks, resulting in the Basin and Range structure definitive of the Province today (Cole *et al*., 1989). Volcanic rocks consisting of silicic tuffs and lavas and basaltic lavas were erupted in the Province during the middle Cenozoic Era (Stewart and Carlson, 1978). The resulting southwest Nevada volcanic field contains at least seven large and partially overlapping calderas that are partially coincident with the mesas in the northwestern part of the NTS. Volcanic activity decreased dramatically during the late Miocene within the southern portion of the Basin and Range Physiographic Province. During the late Miocene to the Quaternary, volcanism was limited to minor basaltic flows and a complete absence of silicic volcanism.

Crustal extension, folding, and faulting continue to the present in the Basin and Range Province. There is evidence that Basin and Range crustal extension occurred in at least two stages on the NTS. The early phase, about 16 to 14 million years ago (Ma), consisted of high-angle northwest- and northeast-trending normal faults. The later phase, post-11 Ma, consisted of slightly steeper dipping north/south-trending normal faults. The earlier phase is thought responsible for several minor topographical troughs discernable on isopach maps of older ash-flow units and for the recently reinterpreted low-angle faults in the Mine Mountains area (Cole *et al*., 1989). The later phase precipitated the present basin-forming faults (Dockery-Ander, 1984). Erosion of the uplifted mountain ranges has progressively filled the basins at the NTS with up to 1,200 m (3,936 ft) of gravel, sand, and silt.

2.1.5 HYDROLOGY

2.1.5.1 SURFACE WATER

The NTS is located within the Great Basin, a closed hydrographic province (actually comprised of a sevier at closed hydrographic basins). The closed hydrographic basins of the NTS (most notably Yucca and Frenchman Flats) are subbasins of the Great Basin. Streams in the region are ephemeral, flowing only in response to precipitation events or snowmelt. Runoff, conveyed by ephemeral streams to the bottom of the closed hydrographic basins, collects on playas. Two playas occur on the NTS: Frenchman and Yucca Lakes, which lie in Frenchman and Yucca Flats, respectively. While water may stand for a few weeks on the playas before evaporating, the playas are dry most of the year. Surface water may leave the NTS in only a few places, such a Fortymile Canyon in the southwest portion.

Springs are the only natural sources of perennial surface water in the region. There are 20 known springs or seeps on the NTS (Hansen *et al*., 1997). Most water discharged from springs travels only a short distance from the source before evaporating or infiltrating into the ground. Other surface waters on the NTS include impoundments located throughout the NTS constructed for operations. These are numerous, and include open industrial reservoirs, containment ponds, and sewage lagoons. Surface water is not a source of drinking water on the NTS.

2.1.5.2 GROUNDWATER

The NTS is located within the Death Valley groundwater flow system, one of the major hydrologic subdivisions of the southern Great Basin (Waddell *et al*., 1984; Laczniak *et al*., 1996) (Figure 2.3). The Death Valley groundwater flow system covers an area of about 40,920 square kilometers (km^2) (15,800 square miles [mi^2]) and consists primarily of volcanic rock in the west and carbonate rock in the east. This flow system is estimated to transmit more than 86 million cubic meters (m^3) (70,000 acre-ft) of groundwater annually. Most of this flow moves through a thick sequence of Paleozoic carbonate rock extending throughout the subsurface of central and southeastern Nevada and is sometimes referred to as the "Acentral carbonate corridor."

Winograd and Thordarson (1975) characterized the major water-bearing units of the NTS. Laczniak *et al*. (1996) revised these units into five general designations: (1) the basement confining unit, (2) the carbonate-rock aquifer, (3) the Eleana confining unit, (4) the volcanic aquifers and confining units, and (5) the valley-fill aquifer. Although each of these units has internal variations and complexities, and although different regions are influenced by different combinations of these units, the five designations provide a simple yet accurate overview of the subsurface hydrogeology. The carbonate-rock aquifer is comprised of highly transmissive materials and is the major pathway for regional groundwater flow beneath the NTS because of its solubility in groundwater and secondary fracturing due to Cenozoic tectonic activity.

The divisions of different groundwater flow systems within the NTS are based on the concept of groundwater subbasins, defined as the area that contributes water to a major surface discharge. Three principal groundwater subbasins have been identified within the NTS region as the Ash Meadows, Oasis Valley, and Alkali Flat-Furnace Creek Ranch subbasins (Figure 2.3). However, the boundaries between these subbasins are not well defined and are the subject of current debate.

The depth to the groundwater in wells at the NTS varies from about 260 m (853 ft) below land surface in the southern part of the NTS to more than 610 m (2,000 ft) under the upland portions of Pahute Mesa (Russell, 1994). Perched groundwater is known to occur in some parts of the NTS, mainly in the volcanic rocks of the Pahute Mesa area, which accounts for groundwater depths less than 183 m (600 ft). In general, groundwater within major water-bearing units beneath the NTS flows south and southwest. The flow system extends from the water table to a depth that may exceed 1,494 m (4,900 ft) where the transmissivity of the rocks becomes much smaller (Energy Research and Development Administration [ERDA], 1977).

Within the Death Valley flow system, recharge occurs as underflow from upgradient areas and from infiltration of precipitation primarily in the northern and eastern mountain ranges, while discharge occurs primarily in the southern and western low-lying valleys. Discharge locations are controlled by the presence of low-permeability materials that force groundwater to the land surface or by the lower elevations of Death Valley.

The groundwater underlying the NTS and surrounding areas is derived from two sources: underflow from basins upgradient of the area and from recharge over the upland areas within the NTS boundaries. Cumulative underflow from adjacent areas is significant. Harrill *et al*. (1988) estimated underflow of 3.9×10^7 m^3/yr (32,000 acre-ft/yr) discharge from Indian Springs Valley westward into Frenchman Flat. They also estimated that the underflow of 6.2×10^6 m^3/yr (5,000 acre-ft/yr) and 1.2×10^6 m^3/yr (1,000 acre-ft/yr) is derived from Kawich Valley and Gold Flat, respectively. In addition, Winograd and Thordarson (1975) estimated that small to moderate volumes of water (0.1 to 7.4×10^6 m^3/yr [80 to 6,000 acre-ft/yr]) may enter the carbonate aquifer in the Ash Meadows groundwater basin by underflow from the northeast. Thus, the total underflow onto the NTS is at least 4.7×10^7 m^3/yr (38,000 acre-ft/yr), based on Harrill *et al*. (1988) and could be as high as 5.4×10^7 m^3/yr (44,000 acre-ft/yr) if the inflow suggested by Winograd and Thordarson (1975) is considered.

Upland recharge occurs predominantly by slow percolation of surface water through the unsaturated zone that overlies the water table. Most of this recharge is restricted to higher elevations where precipitation is greatest, and along upland canyons and alluvial fans adjacent to upland areas. Recharge from upland areas of the NTS is far more limited, about 4.2×10^6

m^3/yr (3,400 acre-ft/yr), or about one-tenth of that derived from underflow. Most of the recharge originates over the upland areas of Pahute Mesa, Timber Mountain, and the Belted Range.

Most of the natural annual discharge from the Death Valley flow system is transpired by plants or evaporated from soil and playas in the Amargosa Desert and Death Valley. This discharge is estimated to be about 2.1×10^7 m^3/yr (17,000 acre-ft/yr) from the Ash Meadows area and about 1.1×10^7 m^3/yr (9,000 acre-ft/yr) from the Alkali Flat-Furnace Creek Ranch area (Rush, 1970). Less than 1×10^6 m^3/yr (a few hundred acre-ft/yr) may continue southward through alluvium of the Amargosa arroyos, and as much as 6.2×10^6 m^3/yr (5,000 acre-ft/yr) may flow westward from the Amargosa Desert to springs in Death Valley (ERDA, 1977). Discharge at Ash Meadows and Oasis Valley is structurally controlled; the presence of low-permeability rocks retards regional flow. This geologic setting creates high water levels that result in local spring discharge and evapotranspiration. However, some water may flow into the Alkali Flat-Furnace Creek Ranch area and discharges at springs near Furnace Creek Ranch (Winograd and Thordarson, 1975).

Within the NTS, groundwater discharge is much smaller and is limited to a few springs in the upland areas and several wells. The springs discharge waters from perched zones in the upland areas. Discharge from the springs is small; three springs discharge between 8 and 30 liters per minute (L/min) (4.3 and 16×10^3 m^3/yr, or 2 and 8 gal/min), while the rest discharge less than 4 L/min (1 gal/min) (DOE, 1988a). The springs are important sources of water for wildlife, but they are too small to be of use as a water supply source. Discharge to springs and wells is small compared to the natural discharge of groundwater from the NTS through subsurface flow to Rock Valley and the Amargosa Desert, which totals an estimated 5.2×10^7 m^3/yr (42,000 acre-ft/yr) (Harrill *et al*., 1988).

2.1.6 WATER RESOURCES

Groundwater is the only local source of potable water on the NTS. Potable and industrial water supply wells for the NTS produce from the carbonate, volcanic, and valley-fill aquifers. The NTS water system consists of 14 supply wells. Supply well production is on the order of tens of thousands of cubic meters per annum. The potable water is pumped or trucked from the wells to the points of consumption.

In the vicinity of the NTS, both groundwater and springs are used primarily for agriculture, mining, and human consumption. Water use in this area is strictly governed by the Office of the State Engineer and the Division of Natural Resources. Current groundwater management policy requires that total withdrawals do not exceed the perennial yield.

Laczniak *et al*. (1996) reports that the Death Valley flow system is estimated to transmit more than 8.6×10^7 m^3 (70,000 acre-ft) of groundwater annually.

2.2 SOURCES OF RADIATION

2.2.1 ENVIRONMENTAL RESTORATION PROJECTS

The Federal Facility Agreement and Consent Order (FFACO) between the state of Nevada Department of Conservation and Natural Resources, Division of Environmental Protection; the DOE; and the U.S. Department of Defense (DoD), is the primary regulatory driver for DOE environmental restoration activities in Nevada. The corrective action strategy in the FFACO includes four steps: (1) identify corrective action sites (CASs); (2) group the CASs into corrective action units (CAUs); (3) prioritize the CAUs for funding and work; and (4) implement the corrective action investigations and/or corrective actions, as applicable. Based on the source of contamination, CASs have been organized into four categories: (1) Industrial Sites, (2) Underground Test Area (UGTA) Sites, (3) Soil Sites, and (4) Offsites. Offsite CASs are not monitored under the RREMP and are, therefore, not discussed.

Industrial Sites

The FFACO identifies approximately 1,150 industrial sites where activities were conducted that supported nuclear testing. The functional categories of these CASs range from landfills, mud pits, and leachfields, with or without radiological contamination; to discarded or abandoned materials such as drums, batteries, and lead materials. CASs with materials that are easily disposed are considered to be housekeeping sites and account for approximately one-third of all industrial CASs. The radionuclide source inventories at the industrial sites have not been identified at this time; however, they are believed to be negligible compared to soil sites.

Underground Test Area Sites

The FFACO identifies 908 historical nuclear detonations that occurred in shafts or tunnels at the NTS. They are categorized into 878 CASs assigned to the UGTA. These CASs are grouped into six CAUs (Figure 2.4) which are geographically distinct and which have different contaminant sources and geologic and hydrogeologic characteristics related to their location. The Yucca Flat CAU consists of 717 CASs. The other CAUs are Frenchman Flat (10 CASs), Western Pahute Mesa (18 CASs), Central Pahute Mesa (64 CASs), Rainier Mesa/Shoshone Mountain (66 CASs), and Climax Mine (3 CASs).

The quantity of radioactivity in the subsurface is estimated at approximately 300 million Ci (DOE, 1996a). No formal assessment of these source terms is yet available. The nature and extent of groundwater contamination will not be known definitely until local-scale flow and transport modeling for UGTA CAUs are completed.

Underground nuclear tests introduced a variety of radionuclides into the subsurface: unexpended nuclear material, direct products of the nuclear reaction, and radionuclides produced by neutron activation in the immediate vicinity of the explosion (Borg *et al*., 1976). The sum of the radionuclides is known as the radiologic source term. In general, the distribution of radionuclides within the cavity and chimney complex is fractionated; the heavier refractory species are concentrated within nuclear explosive melt glasses, and the lighter volatile species are concentrated higher in the chimney. Some unknown fraction of the radiologic source term has been transferred or is transferable to the groundwater regime through a variety of physicochemical mechanisms. This fraction is known as the hydrologic source term. The following paragraphs discuss the mechanisms of radionuclide release of the hydrologic source term and describe the expected radionuclides in the groundwater derived from the hydrologic source term.

There are three possible mechanisms for release of radionuclides from an underground test: prompt fracture injection, groundwater transport of radionuclides in the chimney/cavity complex, and leaching of radionuclides from nuclear explosive melt glass.

The enormous pressures generated during a nuclear test may create or enlarge preexisting fractures in the rock, injecting radioactive material considerable distances from the working point (Nimz and Thompson, 1992). Fractures may be vertical, subvertical, or horizontal. Radionuclides deposited by prompt fracture injection will probably be transported further by groundwater transport.

Once the cavity and chimney are infilled with groundwater (i.e., after the test-induced groundwater mound has decayed and temperature within the cavity has dropped below 100 C [212 F]), the portion of the radionuclides in the chimney not adsorbed on rock surface or retained by the melt glass will be available for transport. Radionuclides with low to moderate melting points that behave in a partly volatile fashion (the alkali metals, ruthenium, uranium, antimony, tellurium, and iodine) may be deposited within the chimney. In addition, ^{3}H and the gaseous radioactive isotopes of argon-87 (^{87}Ar), krypton-87 (^{87}Kr), and xenon-137 (^{137}Xe) may be distributed within the chimney following a nuclear explosion (Borg *et al*., 1976). Of concern are ^{87}Kr and ^{137}Xe, which decay to strontium-90 (^{90}Sr) and cesium-137 (^{137}Cs), respectively, within three minutes (Smith, 1993). Streaming of these gaseous precursors may allow ^{90}Sr and ^{137}Cs to be deposited inside and outside the chimney. Other radionuclides present in chimney/cavity groundwater samples include ruthenium-106 (^{106}Ru), cobalt-60 (^{60}Co), antimony-125 (^{125}Sb), cerium-144 (^{144}Ce), europium-125 (^{125}Eu), and technetium-99 (^{99}Tc). In all cases, activity is due predominantly to ^{3}H.

Recent studies conducted for the UGTA subproject on groundwater samples from two wells drilled near the TYBO test on Pahute Mesa have found small amounts of plutonium (Pu). The data indicate that the Pu was transported in groundwater as colloidal material (Los Alamos National Laboratory [LANL], 1998).

Considering data summarized by Smith (1993), the amount of radionuclides leached from melt glass is expected to be minor. Glass will incorporate chemical species with higher melting points; i.e., the so-called refractory radionuclides (plutonium, rare earth, and alkaline earths). The glass will provide a long-term reservoir of radionuclides, but leaching of melt glass will probably not introduce large amounts of radionuclides into the groundwater regime.

Soil Sites

Soil Site CAUs consist of surface and shallow subsurface soil contamination resulting from various types of nuclear experiments or testing. The FFACO identified the following types of soil site CAUs:

- Sites of atmospheric testing (including airburst, airdrop, balloon, rocket, surface, and tower types).
- Sites of safety experiments that produced no nuclear explosions, but created surface contamination.
- Sites of cratering tests where nuclear devices were used to excavate large volumes of earth.
- Sites of classified hydronuclear experiments.
- Sites of nuclear rocket engine tests.
- Uncontained subsurface nuclear tests.

Soil contamination at the NTS resulted primarily from atmospheric testing of nuclear devices (1951-1962) and safety shots (1954-1963). Locations of atmospheric tests and safety shots at which contamination still exists are shown in Figure 2.5. Atmospheric tests have contaminated soil near the test ground zero (GZ) at a few sites throughout the NTS. Safety shots have distributed plutonium particulates over surface soils in Plutonium Valley. Near-surface cratering experiments dispersed radioactive rock and soil about the GZ. Some shallow and deep underground tests inadvertently have vented radioactive material to the surface. Table 2.2 displays the numbers of atmospheric and underground tests, including cratering experiments, performed in each of the NTS Operational Areas.

The Radionuclide Inventory and Distribution Program (RIDP) was started in 1981, conducting aerial surveys, *in situ* spectrometry, and soil sampling to determine the areal distribution of radionuclides (McArthur, 1991). Aerial surveys were carried out with an array of helicopter-mounted NaI(Tl) scintillation detectors to identify regions with contamination. *In situ* spectrometry measurements were carried out at areas that aerial surveys identified as contaminated. The *in situ* measurements were made with a collimated, high-purity germanium detector suspended about 7.4 m (24 ft) above the ground. Spectral analysis was used to compute concentrations of radionuclides from the energy spectrum of the gamma pulses reaching the detector. When peaks were not detected in regions thought contaminated, inventories were assigned, based on the measurement detection limit. This method overestimates inventory in areas with little contamination. The locations of the *in situ* measurements were determined using a microwave ranging system.

Soil samples were collected at sites of *in situ* measurements to determine the depth distribution of radionuclides and to measure concentrations of radionuclides that do not emit strong gamma rays. At most sites, four samples from the top 15 cm (5.9 in) of soil were collected. At a few sites, such as the SEDAN crater (a large crater produced as the result of a Plowshare Program experiment in peaceful uses of nuclear explosives), six samples were collected from the top 30 cm (11.8 in) of soil. Gamma spectrometry was used to determine the depth distribution. Some contaminated areas were not surveyed because they were inaccessible. Inventories in these areas were estimated from assumed radionuclide concentrations and the sizes of the areas.

The significant radionuclides for most of the areas include americium-241 (^{241}Am), ^{238}Pu, $^{239+240}$Pu, ^{60}Co, ^{137}Cs, ^{90}Sr, ^{152}Eu, ^{154}Eu, and ^{155}Eu. The estimated inventories of these ten radionuclides in each NTS area, as of January 1, 1990 (McArthur, 1991), are presented in Table 2.3. The total activity remaining on surface soils in the NTS, including all detectable radionuclides, is estimated at 2,368 Ci (Shott *et al*., 1997a; Table 2.2).

2.2.2 WASTE MANAGEMENT SITES

There are two waste management sites on the NTS. These facilities receive low-level and mixed waste from onsite and offsite that meets the NTS waste acceptance criteria. The following is a brief description of activities at the sites.

Area 5 Radioactive Waste Management Site (RWMS-5)

The RWMS-5 is located in northern Frenchman Flat. In 1961, the RWMS-5 began disposal of low-level radioactive waste generated at the NTS. The RWMS-5 began to accept waste from offsite DOE generators for disposal in 1978. Most low-level and mixed waste is disposed in shallow land burial (<11 m [<35 ft] deep). The waste is received in boxes, drums, and nonstandard containers. Interim covers consist of backfilling with 1.2 m (4 ft) of soil to bring the pit to grade and then another 1.2 m (4 ft) of soil above the natural grade. Waste that requires additional containment is buried in a 13.7-m- (45-ft)-deep trench. Historically, Greater Confinement Disposal (GCD) was conducted between 21 and 36 m (70 and 120 ft) in 3-m- (10-ft)-diameter boreholes.

In the near term, transuranic waste is stored aboveground in Area 5 while it undergoes characterization to meet the waste acceptance criteria for the Waste Isolation Pilot Plant facility in New Mexico.

Currently, tritium makes up the majority of the radionuclides. It is mobile in the gas phase and is detected at the facility boundary.

Area 3 Radioactive Waste Management Site (RWMS-3)

The RWMS-3 is located in central Yucca Flat. Operations at the RWMS-3 utilize subsidence craters that have resulted from underground tests for the receipt of low-level waste. There are currently three craters being used for disposal operations and two that are operationally closed that received contaminated debris from the NTS in the past. Currently, Area 3 receives packages that consist of transportainers, super sacks, and bulk materials. Operational closure caps consist of backfilling with 1.2 m (4 ft) of soil to bring the pit to grade and then another 1.2 m (4 ft) of soil above the natural grade.

2.2.3 DIRECT RADIATION SOURCES

Onsite Sealed Sources and Radiation-Generating Items/Devices

There are approximately 800 sealed sources and 17 radiation-generating devices on the NTS. A review of the potential impact these devices and sources could have on the public and environment has determined that no radiological environmental monitoring is needed. The basis for this decision is that the sources are sealed with no significant potential for a release of contamination. Because none of the sources or radiation-generating devices is located near the NTS boundary, the public is protected from the radiation emanating from them, even in accident situations. During normal operations, engineering controls reduce the radiation levels at facility boundaries to low levels.

Offsite Sealed Sources and Radiation-Generating Items/Devices

There are DOE/NV support facilities located in urban or suburban areas managed by BN that have sealed radiation sources or radiation-generating devices that could cause direct radiation exposure to the public. These facilities are the STL in Goleta and Santa Barbara, California; the NLVF in North Las Vegas, Nevada; and WAMO in Washington, D.C.

Radiation-generating devices at STL produce 14 MeV neutrons, electrons up to 2.3 MeV, and X rays up to 2.3 MeV. The NLVF contains over 21,000 curies of ^{60}Co and 1,500 curies of ^{137}Cs, plus smaller quantities of other radionuclides. Sealed sources at WAMO are used for calibration of aerial radiological surveillance instruments and are stored in a hanger with public access. During normal operations, engineering and administrative controls prevent public exposure from these sources.

Three other facilities that support DOE/NV and are managed by BN do not have radioactive sources or radiation-generating devices which could cause public exposure. The Amador Valley Operations in Pleasanton, California; and the Los Alamos Operations in Los Alamos, New Mexico, have no sources or devices. The Remote Sensing Laboratory on the Nellis Air Force Base in Las Vegas, Nevada, has sources with radiation levels too low to cause public exposure.

2.3 RADIONUCLIDES OF CONCERN

Radionuclides of concern were identified and ranked based on the estimated NTS inventory and mobility. The radionuclide inventory sources were the RIDP (McArthur, 1991) for surface soil, plants, and animals; the UGTA inventory estimated for underground test sites in or within 100 m (328 ft) of the water table in the EIS for the NTS (DOE, 1996a) for ground-water, surface water, and the vadose zone; and the performance assessments for the Areas 3 and 5 RWMSs for all media at waste management sites (Shott *et al.*, 1997a; 1997b). The radionuclides listed in Table 2.4 and Table 2.5 represent those most likely to be present and detected by environmental monitoring. The nuclides are listed, left to right, in descending order of expected concentration. No quantitative estimate of concentration is made. Radio nuclides of concern may not be present or may be present at concentrations below current detection limits. Naturally occurring radionuclides are not listed. Naturally occurring radium-226 (^{226}Ra), ^{228}Ra, and uranium may be a concern in groundwater.

Radionuclides of concern for environmental restoration sites are shown in Table 2.4. The air media includes those radionuclides that are volatile and have large inventories or those that have large inventories in surface soils. The noble gas ^{85}Kr was excluded because recent monitoring results indicate it is present at global background levels. Radionuclides in groundwater and surface water were identified as those having large UGTA inventories and low retardation factors. Radionuclides of concern in plants and animals are nuclides with large surface soil inventories and large plant-soil concentration factors or large transfer factors. Radionuclides of concern in surface soils are those with the largest inventories. Radionuclides of concern in the vadose zone are those that have large UGTA inventories. Nonvolatile radionuclides in the vadose zone are assumed to remain mostly in test site cavities. Volatile radionuclides were assumed to be the most widely distributed in the vadose zone, and therefore the most likely to be detected. The nuclide ^{137}Cs was given a higher ranking in the vadose zone because its short-lived parent, ^{137}Xe, is a gas that may migrate before decaying. Therefore, there is reason to suspect that this nuclide may be enriched relative to nonvolatile radionuclides as distance from the source(s) increases.

Radionuclides of concern at waste management sites are shown in Table 2.5. They include those estimated to be present at highest concentrations, based on performance assessment modeling. Volatile radionuclides are the most likely to be detected.

2.4 TRANSPORT AND EXPOSURE PATHWAYS

2.4.1 AIR

The sources described above lead to the presence of a variety of radionuclides in onsite air. These include gaseous and particulate materials as follows:

> Gaseous radionuclides: tritium, radon-222 (^{222}Rn), carbon-14 (^{14}C), and ^{85}Kr.
> Particulate radionuclides: long-lived radioactive isotopes (Pu, Th [thorium], U [uranium], Am, ^{137}Cs, ^{90}Sr, etc.) on soil particles and aerosols.

These airborne radionuclides are inhaled by humans and animals, thus leading to radiation exposure and a resultant absorbed dose. They are also transported to other media, principally by deposition; e.g., on plants, surface-water bodies, and other soil surfaces.

Three of the six facilities managed by BN in support of NTS operations use neutron-, electron-, gamma-, or X-ray-generating devices, either as generating machines or as sealed radioactive sources. The exposure pathway in all cases is direct radiation exposure to any person who happens to intercept the radiation from these sources.

2.4.2 SURFACE WATER

For static water bodies at the NTS, such as man-made containment ponds and reservoirs, when there are no spills, the transport processes of importance are those occurring at the air-water interface, and the water-sediment interface. At the water surface, radionuclides from water may transfer to air by volatilization, and from air to the water by dry and wet deposition of aerosols, and by wet dissolution. Sediment deposition, sediment resuspension, sediment burial, and diffusive exchange of water between the water column and the pore water are the transport processes whereby radionuclides are exchanged between water and sediments accumulated in the ponds. For running water, such as occurring during spills, and runoff following storms in channels and arroyos, dissolved fractions of the radionuclides in water are transported downstream. Radionuclides attached to sediments are transported with suspended sediment. Volatilization of tritium from surface water to air occurs at the NTS. Airborne Pu from contaminated soils has the potential to be deposited on water bodies. When water bodies dry up, radionuclides attached to sediments may become airborne.

There are no significant exposure pathways associated with surface waters. Surface waters are not used for drinking water at the NTS, and inhalation and external radiation exposure pathways are relatively insignificant.

2.4.3 GROUNDWATER

Release of radionuclides from test cavities at the underground test areas below the water table will continue to occur by dissolution, desorption, leaching, and diffusion. Radionuclides dissolved in groundwater are transported by advection and dispersion. Drinking water at the NTS is obtained from a network of wells drilled into the local and regional aquifers. Therefore, several onsite drinking water wells are potentially at risk of being contaminated by the expanding radionuclide plumes. Additionally, according to recent iterations of the UGTA groundwater flow model, several of the springs in the Oasis Valley discharge area may also be impacted in the future. Dose to humans from groundwater is via ingestion.

2.4.4 SURFACE SOIL

Contaminated surface soils provide a source of radioactivity to air, water, plant, and animal pathways. Potential routes of migration include resuspension in air and surface water flows and ingestion by game animals that move offsite. Resuspension into the air and movement away from the restricted areas could lead to inhalation by humans or animals. Game animals may ingest contaminated soil or vegetation which has taken up radionuclides. Direct exposure to external radiation from the soil surface occurs among onsite plants and animals, but is considered unlikely for the public. Contaminated soil sites are under active institutional control. The sites are located in areas of restricted access and inadvertent human intrusion is prevented by fencing and posted warnings.

2.4.5 VADOSE ZONE

Exposure to radionuclides while in the vadose zone is unlikely; however, migration in the vadose zone can provide a source of radioactivity to direct air, water, plant, and animal pathways. Potential routes of migration include upward movement (from buried waste packages at the RWMSs or from radionuclide contaminants in industrial sites) to the soil surface through advection, gaseous diffusion, plant uptake, and bioturbation. Downward movement to the water table is considered unlikely at these sites. These sites are currently under active institutional control and do not constitute a health threat to either workers or the general public. Potential environmental receptors are game animals, which may ingest contaminated soil or vegetation which has taken up radionuclides. In addition, resuspension into the air and movement away from the restricted areas could lead to inhalation by humans or animals.

2.4.6 PLANTS

The primary source of contamination to plants is from radionuclides distributed throughout the soil profile in the form of soil and soil water. Radionuclides may also adhere to the surfaces of roots, or they may be resuspended by wind and deposited on plant surfaces such as leaves, stems, and seeds. Roots may absorb radionuclides as inorganic molecules dissolved in water or organic compounds produced by microorganisms and from decomposition of old vegetation. Radionuclides within the plant may be transported to various plant parts and incorporated into a variety of organic compounds. Tritiated water may leave the plant during photosynthesis as water vapor or as a gas where it is diffused into the air.

2.4.7 ANIMALS

Wildlife obtain radionuclides primarily from the ingestion of vegetation. Animals which eat resuspended soil on plant leaves and soil adhering to the roots and ingest soil while grooming or burrowing may obtain a body burden of radionuclides. Animals may breathe contaminated air and drink contaminated water. Radionuclides pass through animals and return to the soil or air through the animal’s feces, urine, or exhaled air (e.g., tritiated water vapor).

Predatory animals, like large birds or meat-eating animals, may also obtain radionuclides by eating contaminated animals such as insects or small mammals. Game animals which obtain a body burden from ingesting radionuclides may migrate offsite and be hunted and eaten, thereby transferring radionuclides to humans. Also, offsite livestock may ingest airborne radionuclides deposited on vegetation and transfer radionuclides to humans through meat or milk. Exposure to source term, distance form source, and time are all variables which affect the concentrations of radionuclides in animal tissues.

Table 2.1 Meteorological Data From the NTS (DOE, 1996a)

NTS Location	Precipitation cm (in)	Average Daily Temperature January		July		Wind Speed km/h (mph)	Direction Wind From	
		Min	Max	Min	Max		Summer	Winter
Pahute Mesa Elev. 2,000 m	23 (9)	-2 C (28 F)	4 C (40 F)	17 C (62 F)	27 C (80 F)	16 (10)	S	NNE
Yucca Flat Elev. 1,195 m	15 (6)	-6 C (21 F)	11 C (51 F)	14 C (57 F)	36 C (96 F)	11 (7)	SSE	NNW
Mercury Elev. 1,314 m	15 (6)	-11 C (12 F)	21 C (69 F)	15 C (59 F)	43 C (109 F)	13 (8)	SW	NW

Table 2.2 Total Radiation Activity in NTS Surface Soils (Shott *et al*., 1997b)

NTS Operational Area	Area (km^2)	(mi^{-2})	Number of Atmospheric Tests	Number of Underground Detonations	Total Curies on Surface Soils
1	70	27	5	4	94.7
2	52	20	7	162	156.4
3	84	32	14	274	133.4
4	42	16	5	39	112.2
5	245	95	15	5	21.1
6	212	82	0	6	21.7
7	50	20	31	62	73.4
8	34	13	3	12	246.9
9	53	20	15	118	161.4
10	54	21	1	70	364.9
11	67	26	4	5	33.8
12	104	40	0	62	97.9
15	96	37	0	3	128.8
16	72	28	0	6	13.9
17	80	31	0	0	68.6
18	230	89	2	3	166.6
19	388	150	0	36	277.7
20	259	100	0	49	165.6
25	578	223	0	0	1
30	150	58	0	5	28
Total	**2,920**	**1,128**	**100**	**921**	**2,368**

Table 2.3 Estimated Inventories of Major Man-Made Radionuclides in NTS Surface Soil (McArthur, 1991)

Area	Radionuclide Inventory (Ci)								
	^{241}Am	^{238}Pu	$^{239+240}$Pu	^{60}Co	^{137}Cs	^{90}Sr	^{152}Eu	^{154}Eu	^{155}Eu
1	4.2	6.5	24	1.1	8.8	15	15	0.1	0.5
2	2.9	8.6	22	1.2	24	46	14	0	0.4
3	4.6	3.1	37	1.0	12	33	18	0.1	0.5
4	6.6	13	40	1.6	12	13	9.1	0	0.2
5	0.6	0.1	4.8	0.6	0.4	0.9	10	0.2	0
6	1.7	3.3	8.4	0.2	2.8	3.5	0	0	0
7	2.2	0.6	16	1.0	5.2	9.2	22	0.2	0.3
8	17	8.0	110	5.7	42	25	4.4	0	0.6
9	4.2	2.2	89	0.7	8.7	13	23	0.2	0.3
10	19	19	110	9.7	84	55	2.2	0.3	5
11	3.3	0.5	29	0	0.5	0.3	0	0	0
12	5.7	8.5	39	1.2	20	17	0	0	0
15	8.0	7.8	63	0.3	19	22	0	0	0
16	0.7	1.5	3.7	0.1	2.9	3.7	0	0	0
17	2.8	4.5	18	1.0	15	19	0	0	0
18	19	5.6	100	0.7	10	17	1.1	0.1	0.8
19	21	32	140	1.1	36	31	0	0	0
20	23	30	41	7.9	5.5	4.3	13	1.6	4.8
25	0	0	0	0	0.2	0.1	0.4	0	0
26	0	0	0	0	0	0	0	0	0
30	3.2	4.5	14	0.8	1.5	1.3	00.7	0.1	0.2
Total	**150**	**160**	**910**	**35**	**310**	**330**	**130**	**2.8**	**14**

Table 2.4 Radionuclides of Concern for Environmental Restoration Sites

Media	Radionuclides of Concern
Air	^{3}H, $^{239+240}$Pu
Groundwater and Surface Water	^{3}H, ^{90}Sr, ^{137}Cs, ^{99}Tc, $^{239+240}$Pu, ^{238}Pu, ^{14}C
Plants	^{3}H, ^{90}Sr, ^{137}Cs, $^{239+240}$Pu
Animals	^{3}H, ^{90}Sr, ^{137}Cs, $^{239+240}$Pu
Surface Soils	$^{239+240}$Pu, ^{90}Sr, ^{137}Cs
Vadose Zone	^{3}H, ^{137}Cs, ^{90}Sr, ^{152}Eu, ^{155}Eu, $^{239+240}$Pu, ^{238}Pu

Table 2.5 Radionuclides of Concern for Waste Management Sites

Media	Radionuclides of Concern
Air	^{3}H, ^{14}C, ^{222}Rn
Groundwater	None During Operational Period
Plants	^{3}H, ^{99}Tc, ^{14}C, ^{90}Sr
Animals	^{3}H, ^{99}Tc ^{14}C, ^{90}Sr
Surface Soils	^{3}H, ^{90}Sr, ^{99}Tc, $^{239+240}Pu$, ^{239}U
Vadose Zone	^{3}H, ^{14}C, $^{239+240}Pu$, ^{238}U

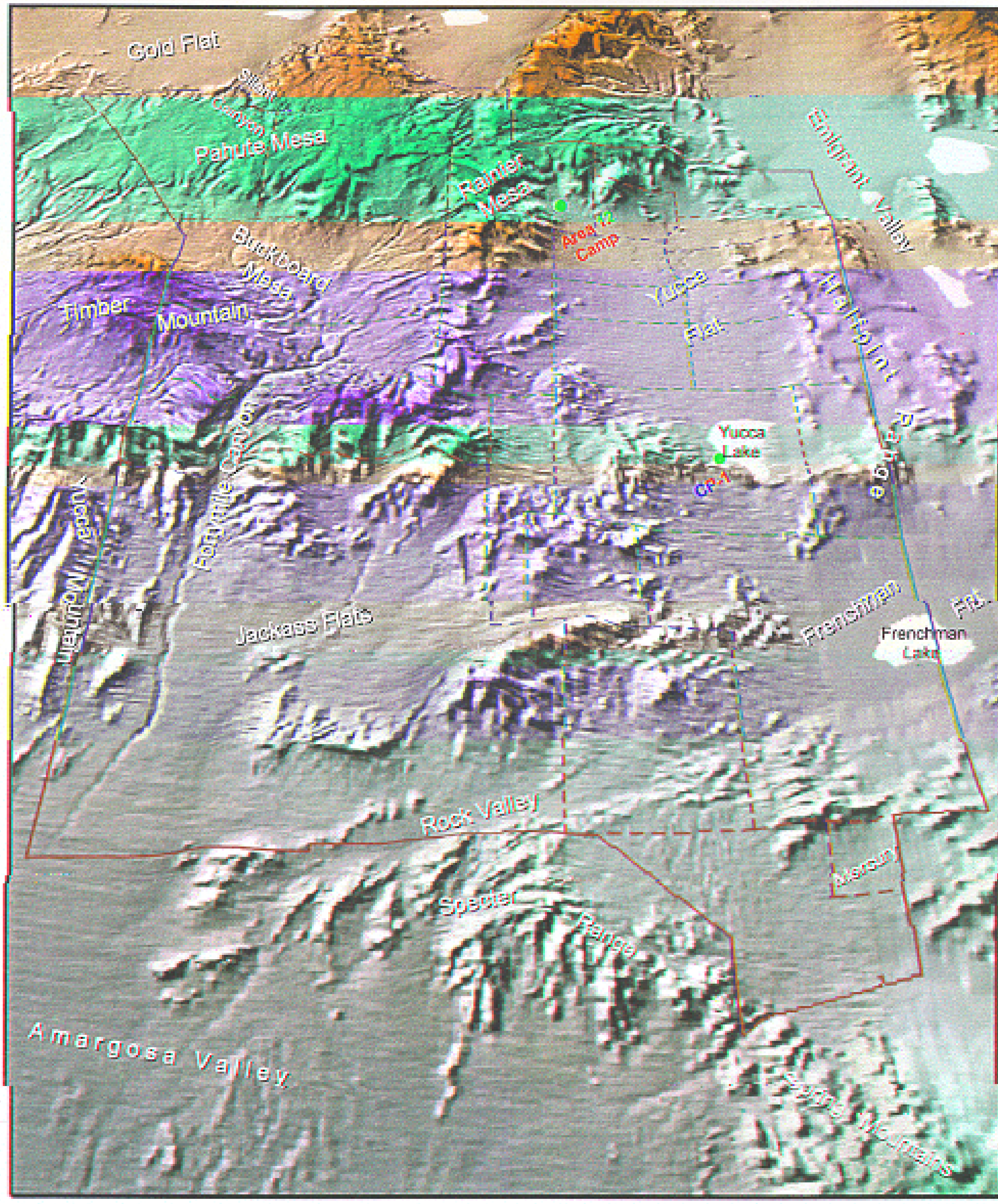

Figure 2.1 Topography of the NTS

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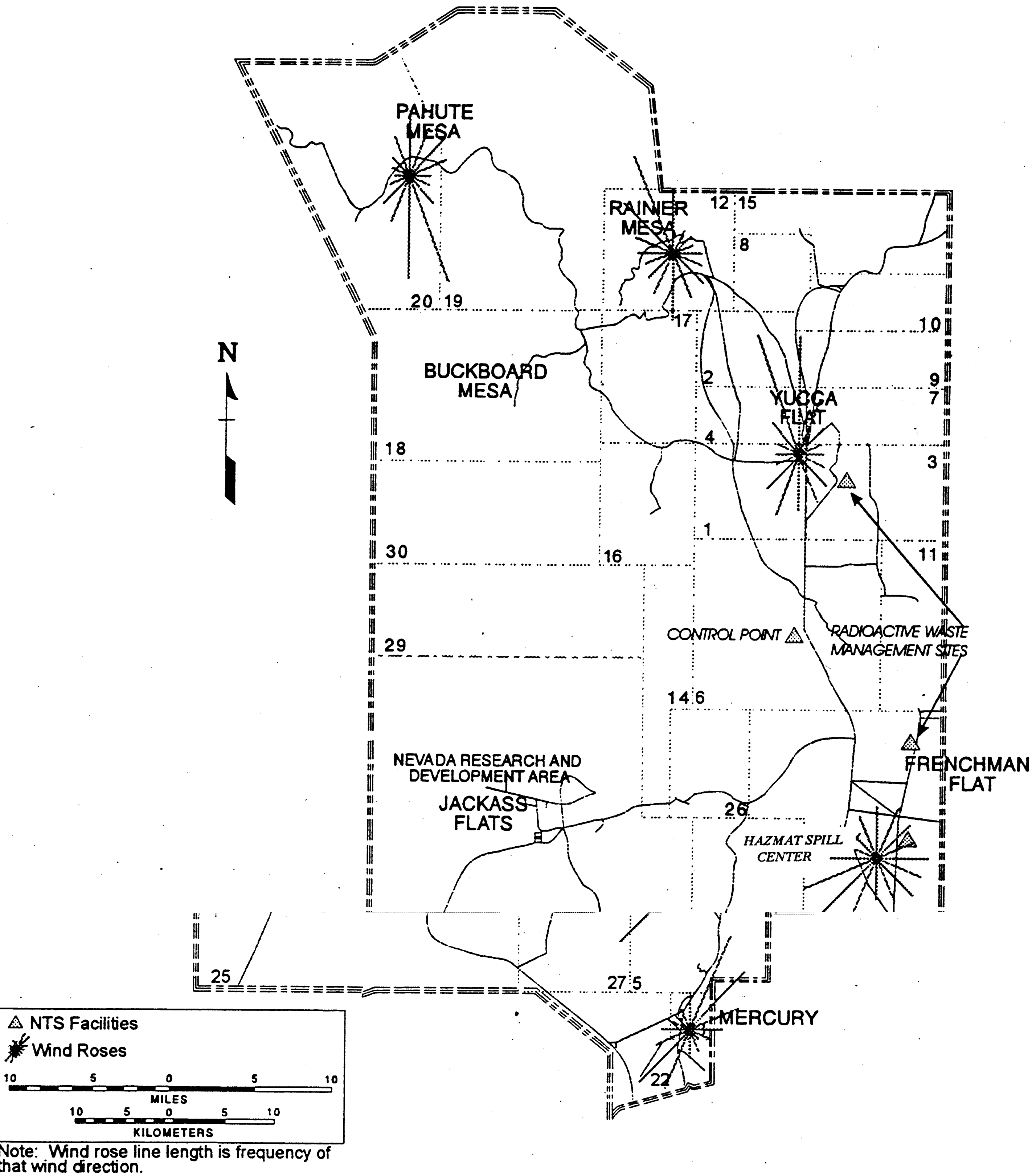

Figure 2.2 Average Annual Wind Direction on the NTS

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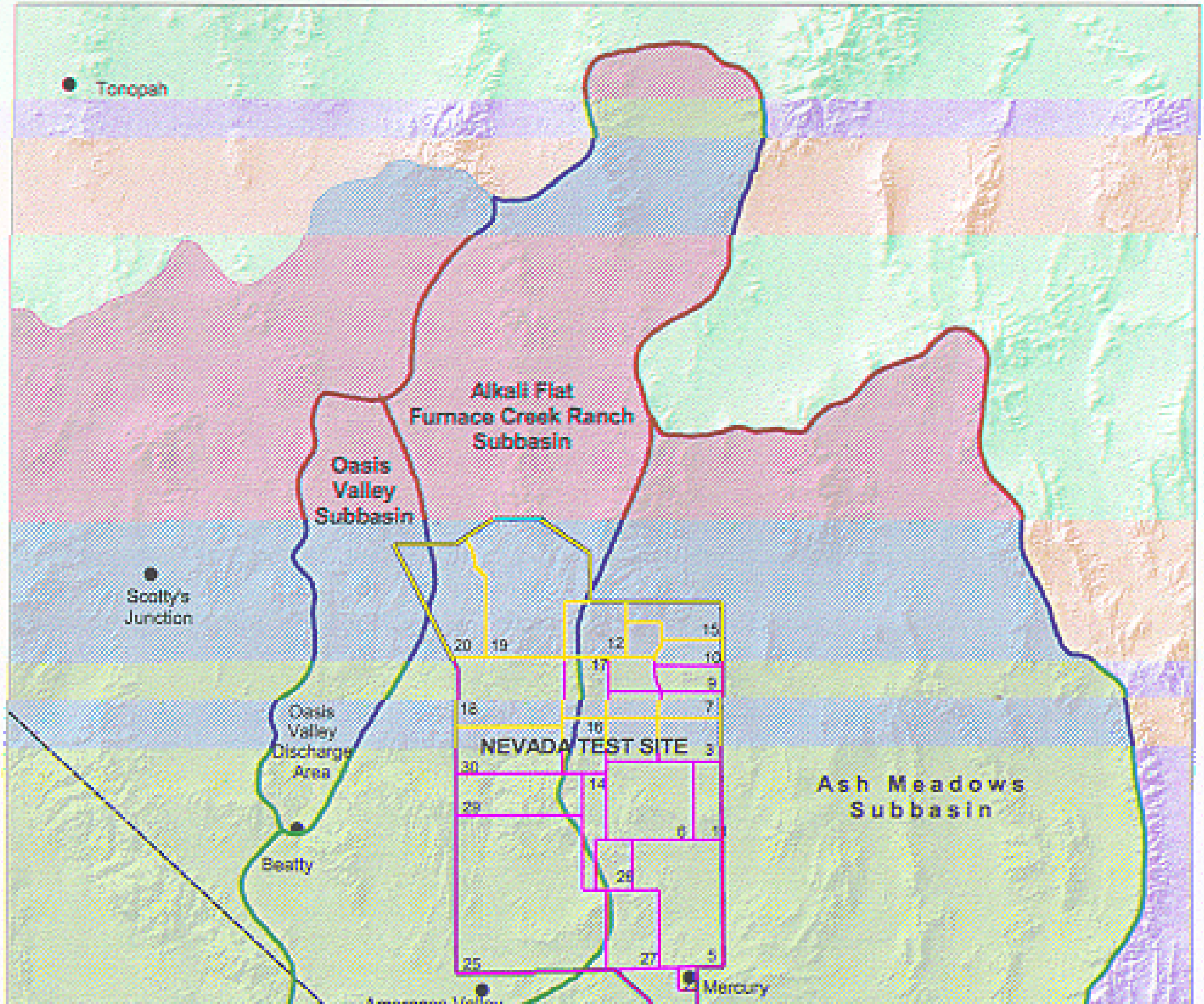

Tonopah
Alkali Flat
Furnace Creek Ranch
Subbasin
Oasis
Valley
Subbasin
Scotty's
Junction
Oasis
Valley
Discharge
Area
Beatty
NEVADA TEST SITE
Ash Meadows
Subbasin
Mercury
Amargosa Valley
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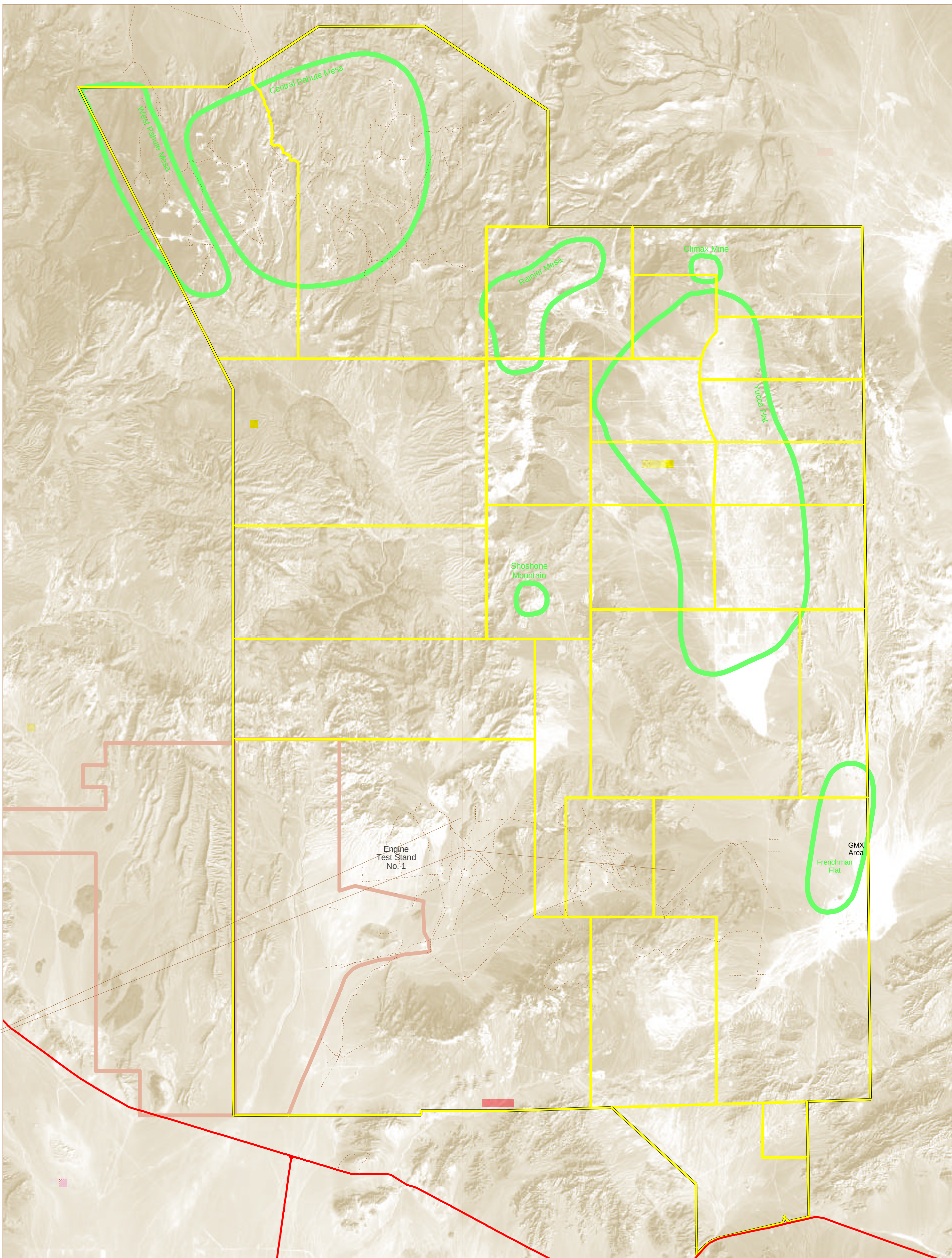

Figure 2.4
Subsurface Radiological Contamination on the NTS

Corrective Action Units (CAU)

In Saturated Zone

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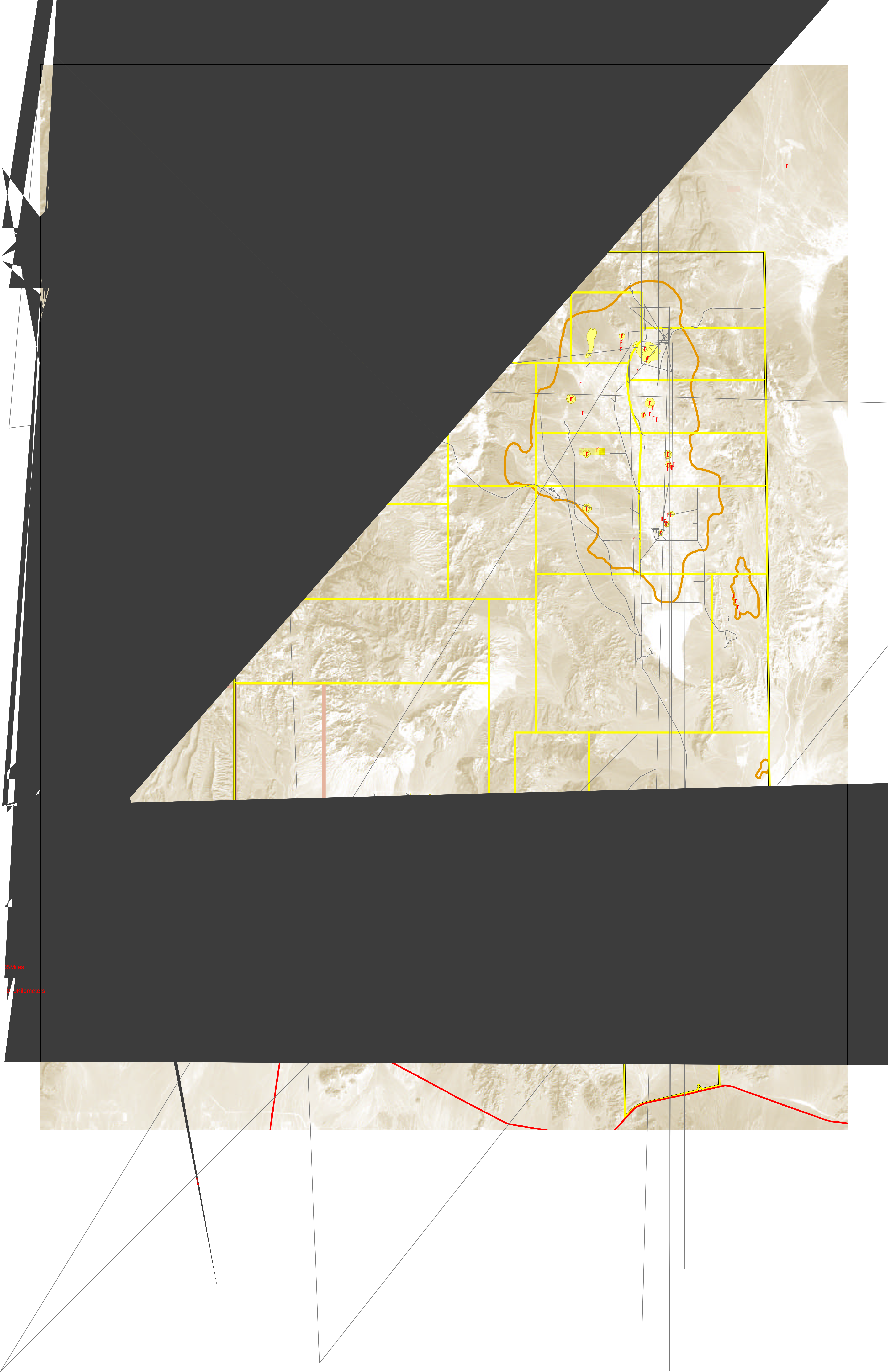
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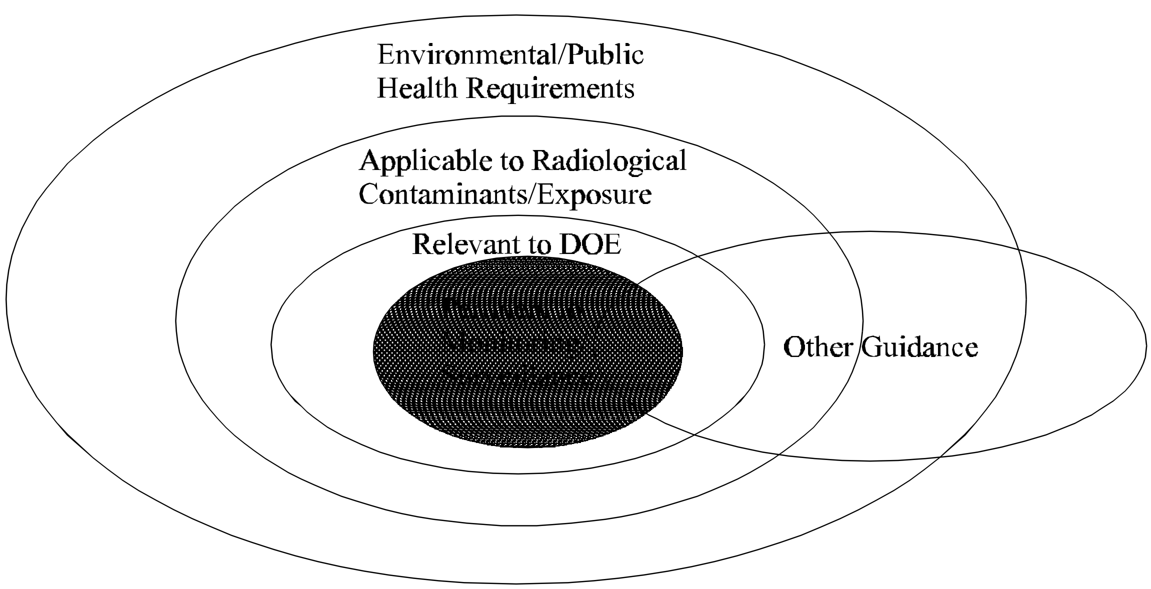
3.0 RADIATION MONITORING REQUIREMENTS

The integrated RREMP is conducted in accordance with applicable requirements and stakeholder concerns. A review of these requirements and concerns was conducted prior to development of the media-specific radiological monitoring designs. In order to identify requirements, a screening process was applied, following the approach of Watts and Johnejack (1994), who developed a process for screening all possible environmental requirements for NTS waste management facilities. Under this approach, the term "requirements" broadly refers to statutes, regulations, and directives. Requirements are screened for identification as "applicable" (e.g., requirements with which DOE/NV must comply on the NTS), "relevant" (addressing requirements which are relevant to activities conducted at the NTS), "pertinent" (providing specific direction to the conduct of activities under this program), and "other guidance" (either providing a conceptually-related approach or consisting of a pending regulatory revision which would apply to the NTS if implemented, but to which DOE/NV is not presently required to comply).

For purposes of developing an integrated radiological monitoring program, only those federal and state requirements pertaining to the environment or to public health were screened. Requirements were then categorized as Applicable if they pertained to radiological contaminants or radiation exposure. Within this subset of Applicable regulations, those that pertained to the DOE were identified as Relevant. Finally, Pertinent regulations were identified as those DOE-relevant requirements which specifically addressed radiological effluent monitoring and environmental surveillance.



(Adapted from Watts and Johnejack [1994])

Requirements categorized as Other Guidance in the diagram above are those found in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE, 1991a). This guidance document provides implementation guidelines for monitoring and surveillance activities required under DOE Orders. Pending regulations were also reviewed for Other Guidance; however, no pending regulations that provided specific direction for the purposes of this RREMP and which were scheduled to be promulgated in the near future were identified as requirements for this plan.

Stakeholder concerns were also considered during development of the RREMP by reviewing public comments expressed during Citizen Advisory Board meetings, Community Technical Liaison Program (CTLP) meetings, other public outreach meetings conducted by DOE/NV, and those which were submitted to DOE/NV during review of the NTS EIS (DOE, 1996a) and were related to environmental and public health radiation issues on and surrounding the NTS. Public comments included those of private citizens, organizations, businesses, and state and federal agencies. Stakeholder concerns that influenced the DQOs or technical design of the monitoring plan are discussed within the descriptions of the monitoring plans provided in Chapter 4.

Table 3.1 summarizes all requirements classified as Relevant or identified as providing Guidance to the RREMP. Tables 3.2 through 3.9 provide a listing, within each media of concern, of those Pertinent radiological monitoring program requirements that are contained within Relevant DOE Orders and federal and state statutes, permits, and agreements. Other Guidance is also listed in this table. Pertinent requirements and Guidance, referred to as Program Elements in the tables, were judged likely to influence the objectives or design of the radiological monitoring plans for each media. For details on requirements for each media, refer to Appendix E, “Data Quality Objectives.”

Table 3.1 Relevant Requirements for the Routine Radiological Monitoring Program

DOE Orders	**Overview**
DOE - 5400.1 General Environmental Protection Program Issued 11-09-88	Establishes environmental protection program requirements, authorities, and responsibilities for DOE operations for assuring compliance with applicable federal, state, and local environmental protection laws and regulations.
DOE - 5400.5 Radiation Protection of The Public and the Environment Issued 02-08-90	Establishes standards and requirements for operations of the DOE and DOE contractors with respect to protection of members of the public and the environment against undue risk from radiation.
DOE - 5820.2A Radioactive Waste Management Issued 09-26-88	Establishes policies, guidelines, and minimum requirements by which DOE manages its radioactive and mixed waste and contaminated facilities.
Federal and State Statues, Regulations, Permits, and Agreements	**Overview**
Title 40 Code of Federal Regulations (CFR) 58, Appendix E	Operational standards for air particulate monitoring.
Title 40 CFR 61, Subpart H, National Emission Standards for Hazardous Air Pollutants (NESHAPs)	Establishes limits on hazardous pollutants including radioactivity that may be emitted into the atmosphere.
Title 40 CFR 141 National Primary Drinking Water Regulations	Controls discharges into groundwater through injection wells, wastewater treatment and disposal sites, distribution of drinking water supplies, and industrial and specific domestic septic tank disposal systems.
Title 40 CFR 191 Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes	Establishes radiation protection standards governing the management and storage of spent nuclear fuel, high-level, and transuranic wastes.
Nevada Administrative Code (NAC) 445A.450, *et seq*. Water Controls	Establishes action levels, remediation standards, and conditions for terminating remediation at contaminated groundwater sites.
Nevada Revised Statutes (NRS) 534.110, Underground Water and Wells	Requires periodic statements of water elevations, water used, and acreage on which water was used from all holders of permits and claimants of vested rights.
NRS 445A.361 *et seq*. Public Water Systems	Outlines the basic legal requirements of public water systems. Establishes the policy of the state to provide water that is safe for drinking and other domestic purposes.
State General Permit GNEV93001	Regulates the ten usable sewage treatment facilities on the NTS. Issued by the Nevada Division of Environmental Protection (NDEP).

Table 3.1 (continued)

Federal and State Statues, Regulations, Permits, and Agreements	Overview
FFACO	Agreement and consent order entered into by the state of Nevada acting by and through the Department of Conservation and Natural Resources, NDEP, the DOE, and the DoD. Addresses environmental restoration of historic contaminated sites at the NTS, parts of the NAFR Complex, the Central Nevada Test Area, and the Project SHOAL Area. Parties agree to negotiate to address needed environmental restoration.
Agreement In Principle (AIP)	Outlines DOE's environmental monitoring commitments to the state of Nevada.
Other Guidance	**Overview**
Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance	Guidance document provides details of recommended approach to radiological effluent monitoring and environmental surveillance.

Table 3.2 Pertinent Program Requirements for Radiological Monitoring of Air

MEDIA: AIR

PROGRAM ELEMENTS	REGULATIONS					
	DOE Order 5400.1	DOE Order 5400.5	DOE/EH-0173T	Title 40 CFR 58, App.	Ttitle 40 CFR 61, Subpart H	AIP with State
PROGRAM OBJECTIVES						
Verify compliance with applicable environmental laws and regulations	x	x	x		x	
Verify compliance with environmental commitments	x	x	x			
Characterize and define trends in the condition of environmental media	x					
Establish baselines of environmental quality	x		x			
Identify and quantify new or existing environmental quality problems	x					
Measure releases, migration, subsidence, and performance changes		x			x	x
PROGRAM DEVELOPMENT						
Use an environmental monitoring program	x	x	x			
Perform exposure pathway analysis and document in Annual Site Environmental Report (ASER)		x	x			
Identify, assess, document, and verify diffuse sources for airborne emissions			x			
Document rationale for monitoring	x		x			
Include quality assurance plan	x		x		x	
PROGRAM DESIGN						
Parameters to be monitored	x		x		x	x
Frequency of monitoring	x		x			
Location of monitoring points	x		x		x	x
Equipment, instrumentation, and facilities to be used for measurements			x	x	x	
Methods for obtaining environmental samples	x		x		x	
Methods of sample analysis	x		x		x	
DECISION RULES						
Identify action levels		x	x			
Verify compliance with dose limits		x				
Predict off-site impacts						x

Table 3.3 Pertinent Program Requirements for Radiological Monitoring of Surface Water

MEDIA: SURFACE WATER

PROGRAM ELEMENTS	REGULATIONS							
	Title 40 CFR 141	DOE Order 5400.1	DOE Order 5400.5	DOE Order 5820.2A	DOE/EH-0173T	Permit GNEV93001	NAC	NRS
PROGRAM OBJECTIVES						x	x	x
Verify compliance with applicable environmental laws and regulations	x	x	x	x		x		
Verify compliance with environmental commitments		x	x					
Characterize and define trends in the condition of environmental media		x	x	x	x			
Establish baselines of environmental quality	x	x	x		x			
Identify and quantify new or existing environmental quality problems		x	x					
Measure releases, migration, subsidence, and performance changes		x	x	x	x	x	x	x
PROGRAM DEVELOPMENT								
Use an environmental monitoring program	x	x	x	x	x	x		
Perform exposure pathway analysis and document in ASER				x				
Identify, assess, document, and verify diffuse sources for airborne emissions								
Document rationale for monitoring	x	x	x					
Include quality assurance plan	x	x	x		x	x	x	x
PROGRAM DESIGN								
Parameters to be monitored	x		x			x	x	x
Frequency of monitoring	x				x	x	x	x
Location of monitoring points	x				x	x	x	x
Equipment, instrumentation, and facilities to be used for measurements	x				x	x	x	x
Methods for obtaining environmental samples	x				x	x	x	x
Methods of sample analysis	x				x	x	x	x
DECISION RULES								
Identify action levels	x	x	x		x	x	x	x
Verify compliance with dose limits	x	x	x	x	x	x	x	x
Predict off-site impacts		x	x	x	x	x	x	x

Table 3.4 Pertinent Program Requirements for Radiological Monitoring of Groundwater

MEDIA: GROUNDWATER

PROGRAM ELEMENTS	REGULATIONS						
	Title 40 CFR 141	DOE Order 5400.1	DOE Order 5400.5	DOE Order 6430.1	DOE/EH-0173T	FFACO	NAC
PROGRAM OBJECTIVES							
Verify compliance with applicable environmental laws and regulations		x	x				x
Verify compliance with environmental commitments		x					
Characterize and define trends in the condition of environmental media		x					
Establish baselines of environmental quality		x		x			
Identify and quantify new or existing environmental quality problems		x		x			
Measure releases, migration, subsidence, and performance changes						x	
PROGRAM DEVELOPMENT							
Use an environmental monitoring program		x	x		x		
Perform exposure pathway analysis and document in ASER							
Identify, assess, document, and verify diffuse sources for airborne emissions							
Document rationale for monitoring					x		
Include quality assurance plan		x			x		
PROGRAM DESIGN							
Parameters to be monitored							
Frequency of monitoring	x				x		
Location of monitoring points					x		
Equipment, instrumentation, and facilities to be used for measurements							
Methods for obtaining environmental samples					x		
Methods of sample analysis	x						x
DECISION RULES							
Identify action levels	x						x
Verify compliance with dose limits							
Predict off-site impacts							

Table 3.5 Pertinent Program Requirements for Radiological Monitoring of Surface Soil

MEDIA: SURFACE SOIL

PROGRAM ELEMENTS	REGULATIONS	
	DOE Order 5400.5	DOE/EH-0173T
PROGRAM OBJECTIVES		
Verify compliance with applicable environmental laws and regulations	x	
Verify compliance with environmental commitments		
Characterize and define trends in the condition of environmental media		x
Establish baselines of environmental quality		
Identify and quantify new or existing environmental quality problems		
Measure releases, migration, subsidence, and performance changes	x	
PROGRAM DEVELOPMENT		
Use an environmental monitoring program	x	x
Perform exposure pathway analysis and document in ASER		x
Identify, assess, document, and verify diffuse sources for airborne emissions		
Document rationale for monitoring		x
Include quality assurance plan		x
PROGRAM DESIGN		
Parameters to be monitored		x
Frequency of monitoring		x
Location of monitoring points		x
Equipment, instrumentation, and facilities to be used for measurements		x
Methods for obtaining environmental samples		x
Methods of sample analysis		x
DECISION RULES		
Identify action levels		
Verify compliance with dose limits		
Predict off-site impacts		

Table 3.6 Pertinent Program Requirements for Radiological Monitoring of Vadose Zone

MEDIA: VADOSE ZONE

PROGRAM ELEMENTS	REGULATIONS				
	DOE Order 5400.1	DOE Order 5400.5	DOE/EH-0173T	DOE Order 5820.2A	Title 40 CFR 191
PROGRAM OBJECTIVES					
Verify compliance with applicable environmental laws and regulations	x	x			
Verify compliance with environmental commitments	x				
Characterize and define trends in the condition of environmental media	x			x	x
Establish baselines of environmental quality	x				
Identify and quantify new or existing environmental quality problems	x				
Measure releases, migration, subsidence, and performance changes		x		x	x
PROGRAM DEVELOPMENT					
Use an environmental monitoring program	x	x	x	x	x
Perform exposure pathway analysis and document in ASER			x		
Identify, assess, document, and verify diffuse sources for airborne emissions					
Document rationale for monitoring	x		x		
Include quality assurance plan	x		x		
PROGRAM DESIGN					
Parameters to be monitored	x			x	
Frequency of monitoring	x				
Location of monitoring points	x			x	
Equipment, instrumentation, and facilities to be used for measurements	x				
Methods for obtaining environmental samples	x		x		
Methods of sample analysis	x				
DECISION RULES					
Identify action levels				x	
Verify compliance with dose limits					
Predict off-site impacts					

Table 3.7 Pertinent Program Requirements for Radiological Monitoring of Plants

MEDIA: PLANTS

PROGRAM ELEMENTS	REGULATIONS: DOE Order 5400.1	DOE Order 5400.5	DOE/EH-0173T
PROGRAM OBJECTIVES			
Verify compliance with applicable environmental laws and regulations	x	x	
Verify compliance with environmental commitments	x		
Characterize and define trends in the condition of environmental media	x		x
Establish baselines of environmental quality	x		x
Identify and quantify new or existing environmental quality problems	x	x	
Measure releases, migration, subsidence, and performance changes			x
PROGRAM DEVELOPMENT			
Use an environmental monitoring program	x	x	x
Perform exposure pathway analysis and document in ASER			x
Identify, assess, document, and verify diffuse sources for airborne emissions			
Document rationale for monitoring	x		
Include quality assurance plan	x		
PROGRAM DESIGN			
Parameters to be monitored	x		x
Frequency of monitoring	x	x	x
Location of monitoring points	x		x
Equipment, instrumentation, and facilities to be used for measurements	x		x
Methods for obtaining environmental samples	x	x	x
Methods of sample analysis	x		x
DECISION RULES			
Identify action levels			x
Verify compliance with dose limits			
Predict off-site impacts			

Table 3.8   Pertinent Program Requirements for Radiological Monitoring of Animals

MEDIA: ANIMALS

PROGRAM ELEMENTS	REGULATIONS		
	DOE Order 5400.1	DOE Order 5400.5	DOE/EH-0173T
PROGRAM OBJECTIVES			
Verify compliance with applicable environmental laws and regulations	x	x	
Verify compliance with environmental commitments	x		
Characterize and define trends in the condition of environmental media	x		x
Establish baselines of environmental quality	x		x
Identify and quantify new or existing environmental quality problems	x	x	
Measure releases, migration, subsidence, and performance changes			x
PROGRAM DEVELOPMENT			
Use an environmental monitoring program	x	x	x
Perform exposure pathway analysis and document in ASER			x
Identify, assess, document, and verify diffuse sources for airborne emissions			
Document rationale for monitoring	x		
Include quality assurance plan	x		
PROGRAM DESIGN			
Parameters to be monitored	x		x
Frequency of monitoring	x	x	x
Location of monitoring points	x		x
Equipment, instrumentation, and facilities to be used for measurements	x		x
Methods for obtaining environmental samples	x	x	x
Methods of sample analysis	x		x
DECISION RULES			
Identify action levels		x	x
Verify compliance with dose limits			
Predict off-site impacts			

Table 3.9 Pertinent Program Requirements for Radiological Monitoring of Direct Radiation

MEDIA: DIRECT RADIATION

PROGRAM ELEMENTS	REGULATIONS		
	DOE Order 5400.1	DOE Order 5400.5	DOE/EH-0173T
PROGRAM OBJECTIVES			
Verify compliance with applicable environmental laws and regulations	x	x	x
Verify compliance with environmental commitments	x	x	x
Characterize and define trends in the condition of environmental media	x		
Establish baselines of environmental quality	x		x
Identify and quantify new or existing environmental quality problems	x		
Measure releases, migration, subsidence, and performance changes		x	
PROGRAM DEVELOPMENT			
Use an environmental monitoring program	x	x	x
Perform exposure pathway analysis and document in ASER		x	x
Identify, assess, document, and verify diffuse sources for airborne emissions			x
Document rationale for monitoring	x		x
Include quality assurance plan	x		x
PROGRAM DESIGN			
Parameters to be monitored	x		x
Frequency of monitoring	x		x
Location of monitoring points	x		x
Equipment, instrumentation, and facilities to be used for measurements			x
Methods for obtaining environmental samples	x		x
Methods of sample analysis	x		x
DECISION RULES			
Identify action levels		x	x
Verify compliance with dose limits		x	
Predict off-site impacts			

4.0 SUMMARY OF MEDIA-SPECIFIC RADIOLOGICAL MONITORING DESIGNS

This chapter briefly describes the objectives and design elements of the RREMP for all media: air, water, soil, biota, and for direct radiation sources. A technical design process was followed to develop this integrated, multimedia program and was styled after the EPA DQO process (EPA, 1994). The detailed steps of the process for each media are presented in Appendix E. During the design process, existing and historical site information and regulatory requirements were reviewed. A summary of the site characteristics, transport and exposure pathways, regulatory requirements, and historical data are presented, as needed, in the following sections to support the monitoring designs. Both onsite and offsite monitoring objectives are addressed under the Plan. Detailed QAASPs for air, water, biota, and direct radiation media are presented in Appendices A through D, respectively.

4.1 AIR MONITORING

Environmental monitoring includes the activities of environmental surveillance, effluent monitoring, and operational monitoring. For air monitoring, the principal difference among these three activities is the placement of the air sampling equipment. Environmental surveillance targets ambient air, but not specific facilities; while the other two activities target facilities or activities. Effluent monitoring is directed at the measurement of a specific emission point, while operational monitoring is used to assess total emissions from an operating facility. The rationale supporting the design of the air monitoring network for NTS addresses these types of monitoring and is discussed in the following paragraphs. During the summer of 1998, DOE/NV entered into discussions with EPA Region 9 concerning the method through which compliance with Title 40 CFR 61, “National Emission Standards for Hazardous Air Pollutants (NESHAPs): Radionuclides” is demonstrated at the NTS. In the event that DOE/NV and Region 9 agree to a different strategy than presented herein, the RREMP will be amended to reflect that strategy and to present the monitoring required under the agreement.

4.1.1 MONITORING OBJECTIVE

The objective for the air monitoring network is to monitor all NTS radionuclide emissions above some reasonable lower limit such that no significant emission source that contributes to calculable offsite exposures is ignored and to ensure that the NTS is in full compliance with the requirements of the Clean Air Act. The regulatory driver for this network includes Title 40 CFR 61, “NESHAPs: Radionuclides,” Subpart H – “National Emission Standards for Emission of Radionuclides Other Than Radon From Department of Energy Facilities.” Other drivers include DOE Order 5400.1 – “General Environmental Protection Program,” DOE Order 5400.5 – “Radiation Protection of the Public and the Environment,” and DOE/EH-0173T – “Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance.” These documents prescribe dose limits and air monitoring requirements. The air monitoring network includes an onsite network that is used to evaluate the NTS contributions to offsite dose; and an offsite air monitoring network through which the offsite effective dose equivalents (EDEs) at affected communities calculated for NESHAPs purposes is confirmed (using high-volume air sampling network).

The monitoring network must fulfill the following requirements:

- Provide point source operational monitoring as required under NESHAPs (any facility which has the potential to emit one-tenth of the standard must be monitored).

  Measure diffuse source emissions (particulate, resuspended particulate, and gaseous emissions from sources which do not individually but do collectively emit one-tenth of the standard).

  Assess source term areas of NTS not previously characterized (using mobile solar-powered units which may access remote areas where grid power is unavailable).

  Provide analytic data to confirm emissions, to detect and identify local and sitewide trends in air, identify radionuclides emitted to air, and detect accidental and unplanned releases.

  Provide data on the concentration of every radionuclide in air expected to contribute to offsite dose.

  Characterize the stability of areas onsite NTS where soil is contaminated by radionuclides.

  Establish measured background values for NTS.

  Provide a means to evaluate the reasonableness of models used in NESHAPs compliance to determine total emissions and emission by radionuclide from the NTS.

  Provide actual data to confirm the reasonableness of offsite EDE calculations prepared as required under NESHAPs.

  Provide measured background values for offsite areas near NTS.

4.1.2 MONITORING PARAMETERS

Over the last two decades, process knowledge, historic air monitoring data, and assessment of radionuclides in soil have established that, based on mobility, risk, and inventory, plutonium, tritium, and some fission products are the predominant cause of exposure to offsite residents and, although of very low levels, are of primary interest with respect to protection of the general public and the environment. Although some uranium has been disposed at the RWMSs, there has been insufficient time for any appreciable amount of radium (the parent of radon) to be produced, and radon emission will not reach any regulatory threshold or contribute to offsite exposure for many years. The parameters that will be monitored at onsite air sampling stations will be radioactivity in particulates and tritiated water (HTO) in air. Particulates will be analyzed for gross alpha activity, gross beta activity, gamma-emitting radionuclides, ^{238}Pu, and $^{239+240}$Pu.

At offsite stations, radioactivity in particulates sampled by high-volume air samplers will be analyzed for gamma-emitting radionuclides and for ^{238}Pu and $^{239+240}Pu$. HTO in air will also be collected at selected locations and analyzed for tritium.

The measured parameters at the onsite air sampling locations will be combined with meteorological and demographic data in approved computer modeling codes, such as EPA's CAP88-PC (Clean Air Package 1988), to compute the dose to the offsite public.

4.1.3 ACTION LEVELS

The selected action level for the air monitoring program is an EDE of 0.1 mrem/yr to any offsite resident from any one source on the NTS, based on NESHAPs. At this time, no single source on the NTS meets this action level, but the sum of all emission sources, proportionately acting on a single offsite receptor, does produce a dose exceeding 0.1 mrem/yr.

4.1.4 SAMPLING AND ANALYSIS DESIGN

For the purposes of this document, as well as for calculation of effective dose to the offsite population, the network of existing NTS air samplers is assumed to be placed according to operational standards (based on guidelines specified in Title 40 CFR 58, Appendix E, as is used by EPA [EPA, 1979]). Also, the particulates collected by air samplers are assumed to be respirable (much less than 10 µm in aerodynamic diameter) and in a soluble chemical form.

4.1.4.1 APPROACH

The most technically defensible and also most efficient approach to NESHAPs compliance at NTS is to use a combination of approaches, including direct monitoring of operational activities, ambient air monitoring and estimating emissions from diffuse sources. The approaches used are:

1. Evaluating operational contributions through measurement of particulate-in-air and tritium-in-air emissions from such sources as the RWMSs in Areas 3 and 5, the Waste Examination Facility (WEF), and Environmental Restoration activities on the Tonopah Test Range (TTR) to determine if the inventory in air is increased as a result of point source operational activities (recent monitoring data indicate that point source operations are presently increasing the inventory of particulate in air and of tritium in air).

2. Monitoring air onsite at locations on the NTS known to be contaminated with radionuclides in order to evaluate the behavior of radionuclide emissions from those locations.

3. Calculation of tritium in air based on the amounts of tritium in surface waters, confirmed through the observed behavior of tritium in air near tritium sources.

4. Modeling particulate emissions in air using a soil resuspension model, based on the observed behavior of particulate emissions in air and confirmed by particulate air monitoring data in selected offsite locations.

5. Calculating EDE, using the CAP88-PC model as prescribed by NESHAPs, to provide dose calculation at any of 320 locations within 80 km (50 mi) of specific emission sources at the NTS (the location of the general public is assessed annually) and confirming the calculation through offsite monitoring. Up to six offsite monitoring locations are used to confirm the reasonableness of the effective dose calculation.

Several approaches to NESHAPs compliance have been considered. One alternative is to use receptor monitoring as the basis for dose. Two significant shortcomings are associated with this method. First, that receptor monitoring presumes in advance where the maximally exposed individual (MEI) may be located. (At many facilities subject to NESHAPs, the location of the MEI is highly predictable, but not at the NTS because of high variability in the behavior of emissions in air and the high variability of wind transport patterns.). Second, to be compliant, receptor monitoring must include all radionuclides which may contribute to 10 percent of dose (which, based on existing data may be caused by plutonium isotopes, HTO, and several fission products). A third shortcoming associated with this alternative is that without onsite monitoring and use of a transport model, there is no way to reconcile offsite dose to onsite emissions. Thus, DOE/NV would have limited ability to respond to changes in offsite dose concentration or location. A second alternative for NESHAPs compliance involves use of receptor monitoring and predictive models, supported by operational monitoring and diffuse source monitoring at selected locations. Issues associated with this practice include inability to evaluate what drives or causes dose, inability to predict where the MEI may occur, and inadequate knowledge of the highly variable environment through which radionuclides in air travel inside the fence line.

In order to achieve NESHAPs compliance, all known or suspected emissions of radionuclides to air are monitored. Where stacks or point sources which have the potential to emit radioactivity sufficient to cause an offsite dose of $\geq$ 0.1 mrem are identified, true effluent monitoring is conducted. Where diffuse sources are known to contribute emissions to air, the behavior of those emissions in air is monitored. Where HTO is expected to exist in ponds, water samples are used to calculate the potential emissions from those ponds. Air monitoring is not conducted at ephemeral sources such as UGTA containment ponds, but is conducted at persistent sources such as E Tunnel pond. Air monitoring is conducted where radionuclides are known to be present in air, for as long as they are present. When monitoring indicates that radionuclides are no longer present at detectable levels, monitoring is terminated. For the purposes of efficiency and conservatism, a resuspension model is used to determine the diffuse emission inputs to CAP88-PC resulting from radionuclides in soils. The soil resuspension model is selected, based on its reasonableness and its conservatism. In other words, the model used slightly overpredicts emissions in air, but is considered appropriately reasonable. Inputs to the resuspension model consist of inventories of the distribution and concentration of radionuclides in soils. At least two sources are used: McArthur (1991) is used for plutonium in soils onsite and the Nevada Applied Ecology Group (DOE, 1992) report is used for plutonium in soils at the TTR. These two reports provide the most reliable inventory of soils contamination at the NTS, although air monitoring indicates that there are diffuse source emissions in air not consistent with reported distribution inventories. The use of the resuspension model is reassessed annually, based on air monitoring trends. To date, air monitoring trends have been consistent with the model outputs; however, in the event that air monitoring trends begin to indicate that the model is not reasonable, the approach to identifying inputs to CAP88-PC will be reassessed. At the time the resuspension calculation is performed for input to CAP88-PC, actual ambient air monitoring data from one area of the NTS is used to verify the calculation (Black, 1997). Other inputs to CAP88-PC include HTO emission in air, calculated from measured concentrations of HTO in surface water, and point source emissions data from effluent monitoring. As of July 1998, no point source qualified for monitoring under NESHAPs requirements (capable of emitting 1 percent of the standard); however, point sources are proposed for operation on the NTS, most notably the Gas Gun, which clearly will require point-source monitoring. Accidental releases from facilities such as U-1a Area 27, or the Device Assembly Facility will be monitored through the ambient monitoring network.

The advantages of this approach are numerous: (1) the approach is fully compliant with the intent of NESHAPs and directly addresses every issue raised in Subpart H of the regulation; (2) the approach allows DOE/NV to respond to any present or future issue raised about offsite dose; and (3) the approach provides data, which may be used in decision making about future activities onsite at the NTS.

4.1.4.2 BENEFITS, REQUIREMENTS, AND USES OF AIR MONITORING

The subject parameters are set forth as follows with their appropriate directives.

Benefits, Requirements, and Uses	**Directives**
All known plutonium emissions and each release point for HTO is a contributor to offsite exposure and must be monitored under both federal law and DOE Orders.	Title 40 CFR 61; DOE Order 5400.1
Many onsite data are used to calculate emissions for input to dose calculation. These inputs include direct measurements of radionuclides in air, documentation of the radionuclide inventory and distribution in soils at the NTS, multiyear meteorological data at the NTS, and current information on where members of the public are located within 80 km (50 mi) of each of the emission sources (about 29 locations are presently identified). A resuspension model is used to calculate onsite emissions because it is observed to be more conservative, and far more efficient, than actually inputting direct-measured data. However, the validity of the resuspension model is based on the behavior of measured emissions in air.	Title 40 CFR 61
Existing and proposed NTS activities, not emitting enough radioactivity to require operational monitoring, will add to the offsite doses and may shift location of the MEI to any location occupied by the public.	Title 40 CFR 61
Accidental releases from sources which would lead to increased emissions must be quantified for their effect on offsite doses. Ambient air monitoring is an appropriate approach to measuring emissions from accidental releases.	Title 40 CFR 61; DOE Order 5400.1

Benefits, Requirements, and Uses	Directives
Onsite data is used to determine if NTS operations are responsible when changes in offsite monitoring data occur (e.g., in 1996, the Lathrop Wells sampler detected a dramatic increase in plutonium. Because onsite concentrations were stable, NTS operations could be demonstrated not to be the likely cause for the increase).	Title 40 CFR 61
If resuspension calculations are questioned, air sample data, together with location of the center of a contaminated area, must be used to calculate emissions, in place of or in confirmation of the calculated resuspension emission.	Title 40 CFR 61
Trends in atmospheric activity must be determined so that causes can be noted and their effects on resuspension activity investigated. Existing air data confirm that radionuclides in ambient air behave in highly variable manners at different locations and under different climatic conditions. There is not a representative pattern of radionuclides in air which can be relied upon to explain this variability.	DOE Order 5400.1
Non-DOE/DoD operations (e.g., Kistler Aerospace construction, travel, and operational activities in Areas 18 and 20) will increase ambient air levels of radioactivity, resuspending more contaminated soil than natural processes. Air monitoring will be required to document this.	Title 40 CFR 61; DOE Order 5400.1
There is a likely potential that the definition of member of the public will be interpreted to include non-DOE/DoD workers onsite at the NTS. Without onsite monitoring data, it will be impossible to reconstruct dose.	DOE Order 5400.1
Environmental restoration operations remove or reduce contamination at specific locations, but postoperational air monitoring is needed to confirm the extent of reduction of airborne activity.	Title 40 CFR 61; DOE Order 5400.1

4.1.4.3 MONITORING SYSTEM DESIGN

The design of an air monitoring network to support compliance with NESHAPs includes an onsite air sampling network that monitors radionuclides in ambient air near their source and an offsite network that monitors radionuclides in ambient air near critical receptor points. In 1998, the predominant radionuclides causing exposure to offsite personnel are plutonium and HTO.

The present ambient air monitoring system on the NTS and NAFR consists of 49 air particulate samplers and 16 samplers for HTO in atmospheric moisture. The existing air monitoring system was designed to monitor suspected locations of radionuclide emission and to measure radionuclide concentrations in places where people lived or worked. The historical data collected by this onsite system provides information upon which a technical and cost-effective air monitoring network for the NTS can be designed. The present offsite network, originally designed around issues associated with atmospheric testing, also provides data which can be used to support offsite network siting design.

The network design must satisfy the directives noted above and must be based on the following principles:

Measurement of air emission at sites with known surface soil contamination.

Air samplers at sites representative of background radioactivity on the NTS.

Assessment monitoring of sites suspected of being contaminated but for which no data exist.

Operational monitoring of activities handling radioactivity and of environmental restoration activities.

Confirmatory monitoring in offsite communities most likely to be impacted by NTS emissions.

4.1.4.4 ONSITE STATION SELECTION

Operational

Operational air monitoring is conducted at any location where radionuclides are transported, treated, or disposed. Any proposed facility or activity at the NTS that involves the transport, treatment, or disposal of radionuclides is reviewed to determine if the operations have the potential to create a dose of one-tenth the standard to any offsite resident. The radionuclides monitored (particulate, gaseous, or HTO in air) are those which process knowledge and/or assessment of radionuclide inventory indicates the potential to contribute to offsite dose. This monitoring can either be continuous in-stack air monitoring, conducted where point source emissions can be directly measured, or upwind/downwind diffuse source monitoring. Where upwind/downwind monitoring is deemed appropriate, preoperational and postoperational monitoring is conducted to establish background prior to operations and to determine if any residual diffuse source emissions may be occurring. In selected cases, preoperational monitoring may provide a background value which can be used in lieu of upwind monitoring. Likewise, in those cases where postoperational monitoring indicates that diffuse sources are still detectable in air, ambient air monitoring is conducted as long as radionuclides are detectable at levels which meet ambient air monitoring criteria. The configuration of operational monitoring is reviewed at least annually, to determine if monitoring data, process knowledge, or radionuclide inventory suggest that the configuration is not optimum. The operational network at the facility may be reconfigured if appropriate.

In 1997, operational monitoring was conducted at three Waste Management facilities (Area 5, the WEF, and Area 3) and at five Environmental Restoration sites. A total of five particulate-in-air samplers were configured around the Area 5 and the WEF, providing upwind/down wind monitoring of both facilities. Four HTO-in-air samplers were also configured around RWMS 5. Two particulate-in-air samplers were located at the Area 3 RWMS, in an upwind/downwind configuration. Two additional particulate in-air-samplers located in Area 3 were on standby, pending the disposal of large volumes of soil from Environmental Restoration activities. One HTO-in-air monitor at the Area 3 was located in a downwind configuration because only small amounts of tritium are expected to be emitted by that facility. Operational monitoring is also conducted at five Environmental Restoration sites, three on the Tonopah Test Range (CLEAN SLATE I, II, and III), and two on the NAFR (Area 13 [Project 57] and DOUBLE TRACKS). Four solar-powered particulate in-air samplers are deployed at these sites, but the configuration of the network at each site is revised based on site-specific criteria during restoration activities. One was also located at the Decontamination Pad. Thus, as of July 1998, there are 15 operational monitors located at NTS operational sites, 10 at radioactive waste management sites, 4 at environmental restoration sites, and 1 at the Decontamination Pad.

Ambient

Two approaches have been considered for the selection criterion for the onsite ambient air sampling (environmental surveillance) network: one based on aerial and ground surveys of radionuclide inventory and distribution in soils on the NTS, and one based on detectability of radioactivity in air, using an evaluation of historical air monitoring data. The latter method, based on actual detection of radionuclides in air, addresses the primary question asked of air monitoring: what and where are detectable concentrations of radionuclides in ambient air? Over the last several decades, ambient and/or operational air monitoring has been conducted at all areas where radionuclides have been believed to exist in air and where grid power has been accessible. More recently, solar-powered air samplers have been used to allow the collection of data in areas suspected of contamination where no grid power has existed. Since the cessation of testing, the air monitoring network has been gradually reduced in size, eliminating areas where radionuclides have not been detected in air and where site activities have ceased. Thus, except for those areas addressed in “Assessments” below, the data set describing the behavior of radionuclides in air at NTS is very large, and is suitable for selection purposes. What remains, then, is defining detection so that a selection criterion can be determined.

For the purposes of this plan, detection was defined as any measurement that exceeded the upper 98 percent confidence limit of background radioactivity. To be conservative, background was chosen to be the upper end of the first quartile of the annual data for 1996 for each measurement made on air samples. Because the 98 percent confidence limit is two standard deviations above the background, the standard deviation was chosen from the air sampling result nearest to the first quartile. Although nearly all gross alpha and gross beta results were above the minimum detectable concentration (MDC), no sampling location met the selection criterion. For $^{239+240}$Pu in air, the background station had a result of $1.56 \pm 0.71 \times 10^{-18}$ µCi/mL, so the selection criterion was any annual average for 1996 that was greater than 3.0×10^{-18} µCi/mL.

Using the selection criterion, 20 locations with annual averages greater than the criterion have been identified. Four of those locations are so close to another air monitoring location that the data sets are considered redundant and unnecessary, leaving 16 sites where $^{239+240}$Pu in air is considered necessary. Two locations were deleted because of low activity and cessation of work, and one was deleted because of the upwind/downwind configuration of other samplers. One additional location has been selected for background monitoring, based on a related criterion: namely the lowest annual average result. The locations of the 14 onsite ambient air particulate samplers are listed in Table 4.1 and shown on Figure 4.1.

A similar criterion, chosen from tritium-in-air data, was used for the HTO network. Based on 1996 data, the upper part of the first quartile plus two standard deviations yielded a cutoff level of 2.4×10^{-12} µCi/mL. Three ambient air sampling locations exceeded the selection criteria and were selected for ambient tritium in air monitoring. BJY (Buster-Jangle Y) was selected because of its central location. No adjustments based on redundant data are made to the tritium-in-air sampling network. A background station was chosen, the 1996 ambient tritium-in-air monitoring station with the lowest observed value was selected (in Area 5 near Water Well 5B). The locations of the HTO-in-air samplers are shown in Table 4.2 and Figure 4.1.

Ambient Air Monitoring Assessments

Although the data on radionuclides in surface soil on the NTS contained in report DOE/NV/10845-02, *Radionuclides in Surface Soil at the Nevada Test Site* (McArthur, 1991), are useful and sufficiently accurate for location of contaminated areas, they are occasionally inconsistent with air monitoring results. To resolve such discrepancies, two solar-powered mobile air samplers will be used to assess airborne radioactivity in locations for which insufficient data exist. These will operate for one year, and those with annual average values that exceed the criterion expressed above will be added to the permanent network. The initial locations that have been chosen are LITTLE FELLER II and BUGGY, both located in Area 18.

The same type of approach will be used to assess previously unsampled areas where tritium in air may exist. Two mobile solar-powered air samplers will be deployed at sites not adequately assessed in previous efforts. The initial locations chosen for this exercise are in Area 20 near SCHOONER (tritium has been detected in adjacent Well PM-1) and in Area 12 on Rainier Mesa near the tunnel vents.

4.1.4.5 OFFSITE STATION SELECTION

For offsite air sampling, two factors drive the network design. The first is that the level of EDE at the offsite communities is sufficiently high that positive detection of radionuclides can be achieved. The second factor is the concern of offsite residents that emissions from the NTS may be high enough to represent a hazard to them. An important function of offsite air sampling is assessment of the validity of NESHAPs compliance as calculated by onsite data; the first factor is related to this, so locations with a history of radionuclide detection are preferred. A review of annual NESHAPs reports for the NTS noted that the MEI was predominantly located in the southwest quadrant from the NTS, although measurable EDEs have been calculated for communities in the northeast quadrant. For the purpose of assessing the validity of onsite data as used for NESHAPs compliance, six offsite sampling locations have been selected. These are the nearest communities in their respective quadrants; those farther away will receive lower exposures. Under NESHAPs, only locations within 80 km (50 miles) of air emission sources are evaluated.

Most of the offsite samplers are generally at locations where the EDE calculated by CAP88-PC is 0.01 mrem or greater. An EDE of 0.01 mrem will result if the air concentration of ^{239}Pu is 3.8×10^{-18} µCi/mL, or about the MDC for the onsite air samplers that operate for one week at 3 cfm (cubic feet per minute) of air. To detect plutonium air concentrations of that level, the MDC should be about 10 percent of that value. This would require a higher sampling rate and/or a longer sampling time. Also, to ensure that measurements are not affected by local deposits, each station location will be characterized by soil sampling and analysis and by surveys with a Field Instrument for Detection of Low-Energy Radiation (FIDLER)-type instrument.

Historically, the MEI has been located either to the northeast or to the southwest of the NTS, consistent with the prevailing wind directions. The locations recommended for this network correspond with these wind directions, have populations of 100 or more, and have had calculated EDEs of 0.05 mrem or more during the last four years or fill gaps in offsite coverage. The locations chosen are Rachel and Alamo to the northeast, Beatty and Amargosa Valley to the southwest, Goldfield to the northwest, and Indian Springs to the southeast. Offsite confirmatory air monitoring also requires HTO-in-air sampling in the predominant downwind direction. Amargosa Valley and Indian Springs are chosen for this function. The locations of these samplers are shown in Table 4.3 and on Figure 4.2.

4.1.4.6 SAMPLING FREQUENCY AND ANALYTICAL PROCEDURES

Air Particulate Samples Onsite

These samples will be collected weekly. The filters will be counted for gross alpha and gross beta activity at least seven days after collection to allow radon progeny to decay. These analyses provide a general indication of airborne radioactivity at each location each week. If results show abnormally high gross alpha or gross beta concentrations, additional detailed analysis will be performed. Monthly, the filters from each location will be combined and analyzed by gamma spectrometry for gamma-emitting fission products, and by alpha spectrometry for ^{238}Pu and $^{239+240}$Pu. The samples will be analyzed for the plutonium radionuclides because they are the radionuclides with the highest probability for detection. Monthly composites reduce the MDC substantially when compared to weekly samples, thus increasing the probability of detecting environmental concentrations of fission products and plutonium.

Air Particulate Samples Offsite

High-volume particulate samples will be collected biweekly, composited monthly, and analyzed by gamma spectrometry and for ^{238}Pu and $^{239+240}$Pu by alpha spectrometry.

HTO in Atmospheric Moisture Samples Onsite and Offsite

These samples consist of HTO collected on a molecular sieve. After a collection period of two weeks, the HTO is extracted and the tritium concentration is determined by liquid scintillation counting. The onsite and offsite HTO sampling regimes are identical.

4.1.5 ACTIONS DEPENDENT ON RESULTS OF AIR MONITORING

The results from air monitoring shall be evaluated for trends, anomalies, and noncompliance with applicable rules and regulations and will be documented in the Annual Site Environmental Report (ASER). If a noncompliance is identified, notifications shall be made in accordance with the impacted rule or regulation and corrective actions taken. Trends and anomalies shall be analyzed to identify the cause. If the action levels are not exceeded, routine monitoring will continue and the results will be documented in the ASER.

4.1.6 SUMMARY OF NETWORK DESIGN OBJECTIVES AND REQUIREMENTS

The network design for air particulate and HTO-in-air sampling meets the requirements expressed in Title 40 CFR 61, Subpart H and DOE Orders as follows:

The Onsite Network Design

Characterizes contaminated areas on the NTS.

Measures diffuse emissions (resuspension and diffusion) from contaminated areas.

Uses solar-powered units to characterize areas with scarce or no data for addition to network.

Uses analyses to confirm emissions, detect trends, determine nuclides being emitted, and detect accidental releases.

Samples HTO and particulates in air and includes a background station for both constituents.

Based on statistical detectability of plutonium in previous air samples.

Satisfies requirements in DOE Order 5400.1, DOE/EH-0173T, and NESHAPs.

The Offsite Network Design

Air sampling design to corroborate offsite EDEs, that have been calculated from NTS emissions, for NESHAPs.

Design includes stations where ◦ 0.05 mrem has been calculated.

Design is based on NESHAPs reports, plutonium detectability, and fallout pattern.

Design meets requirements set forth in DOE Order 5400.1 and DOE/EH-0173T.

4.2 WATER MONITORING

Water sources on and off the NTS have been monitored by DOE to comply with state and federal monitoring and permit requirements, and to report to the public contamination of these sources that are a result of DOE activities. As part of the multimedia review and redesign effort for the RREMP, a monitoring program for water has been developed. This program encompasses both surface water and groundwater monitoring. The groundwater monitoring program described herein fully replaces the Long-Term Hydrologic Monitoring Program (LTHMP) and involves coordination with other routine groundwater monitoring programs at the NTS. Refer to Figure 4.3 for a diagram illustrating the relationship among the various water monitoring programs described in this section.

4.2.1 SURFACE WATER

4.2.1.1 MONITORING OBJECTIVES

The objectives of the routine radiological monitoring program for surface water are to determine (1) if concentrations of radionuclides in surface water bodies at the NTS and its vicinity are a threat to public health and the environment, and (2) if permitted facilities are in compliance with permit discharge limits.

Sampling Locations

The surface water sample locations on the NTS include the E Tunnel containment ponds and nine sewage lagoons; offsite locations include nine natural springs (see Table 4.4; Figure 4.4). The criteria for selection was based on the monitoring objectives. Water sources have been selected based on potential for exposing the public, onsite biota, or the environment to significant levels of radionuclides, or requirements for monitoring under existing state discharge permits.

The NTS containment ponds are zero-discharge facilities. They include ponds receiving water from E Tunnel in Rainier Mesa in Area 12, where nuclear devices have been tested; and ponds built to contain water pumped from groundwater characterization wells. Containment pond waters from N, T, and E Tunnels have been monitored for at least 25 years on a monthly basis and contain several radionuclides, including ^{3}H, ^{238}Pu, $^{239+240}Pu$, ^{234}U, ^{235}U, ^{238}U, ^{137}Cs, ^{125}Sb, and ^{106}Ru (BN, 1997). Fairly constant concentrations of tritium in these waters have been observed over time (BN, 1997), and when water in these ponds evaporates, tritium vapor is released to the atmosphere. N and T Tunnels have been sealed, and discharge currently occurs from E Tunnel only. Active tunnel ponds must be monitored under the current state permit (No. 96021 for E Tunnel ponds). At the ponds associated with groundwater characterization wells, such as those in Area 20, tritium is the dominant radionuclide detected. Other radionuclides have been detected, but at very low concentrations (LANL, 1998).

The nine sewage lagoons at the NTS receive effluents from sewage treatment plants permitted by the state (BN, 1997). Radionuclide monitoring of these lagoons is required under the current state permit.

Several offsite springs have been historically monitored and will continue to be monitored under this program. Six of the historically monitored springs are included in this plan; three springs not previously monitored will be added to the program, one for semiannual and two for annual sampling. These springs are discharge sites for the local and regional aquifers, for which the upgradient direction may be the underground testing area on Pahute Mesa. The offsite springs chosen for the monitoring network are therefore used as groundwater monitoring points in this hydrologic system. Continued monitoring will document and track trends in groundwater quality downgradient of the underground nuclear test sites on the NTS.

Radionuclide levels at all these surface water sources mentioned above have consistently been below the Derived Concentration Guides (DCGs) listed in DOE Order 5400.5 over recent years (DOE, 1996a).

Locations Where Sampling Will Be Discontinued

Onsite open reservoirs, which intermittently contain water pumped from supply wells and are used for industrial purposes, will not be sampled under this monitoring program. Historically, 15 reservoirs on the NTS were sampled periodically, and the concentrations of radionuclides in them were consistently below the DCGs (BN, 1997). Airborne contamination resulting from atmospheric testing has been a primary source of radionuclides in surface waters at the NTS, and airborne contamination from resuspension of radionuclides deposited on surface soils as a result of atmospheric testing has been a secondary source. Since the cessation of worldwide atmospheric testing, fallout has declined to negligible levels as a source of radionuclides in surface waters and resuspension has been observed to be an insignificant source of contamination to surface waters. Groundwater may provide a source of radionuclide contamination to surface waters such as man-made reservoirs; however, the potential for groundwater to become a source to surface waters is monitored through the groundwater monitoring program. For these reasons, monitoring of open reservoirs at the NTS is not required under this program.

Onsite springs will not be sampled under this monitoring program. Historically, nine NTS springs have been monitored, and concentrations of radionuclides in these water bodies have also been consistently below the DCGs (BN, 1997). Like the open reservoirs, the source of their contamination is primarily from historic atmospheric testing activities, including radioactive fallout. Also, the groundwater which feeds these springs is locally derived and is not hydrologically connected to any of the aquifers that may be impacted by underground nuclear tests.

Analyses and Action Levels

All surface water samples will be analyzed by gamma spectroscopy and for tritium. At selected locations, and the new locations where established hydrochemical baselines do not exist, the analysis will be expanded to include gross beta, ^{238}Pu, $^{239+240}Pu$, and ^{90}Sr.

The action levels for the onsite containment ponds and sewage lagoons are established in the permits. For offsite springs, an action level only for tritium was established as 10 percent of the primary drinking water standard (currently 20,000 picocuries per liter [pCi/L] (Title 40 CFR 141)). This health-based action level does not preclude the RREMP from also using lower thresholds at selected locations for early detection of contaminant movement within a CAU or along likely flow paths. Analyses will be expanded to include gross beta, Pu, and Sr or other indicators when the action level for tritium is reached. Analyses may also be expanded upon a management assessment of a detectable level of tritium at sampling locations.

Sampling and Analysis Design

Surface water from onsite containment ponds and sewage lagoons will be sampled and analyzed quarterly for all parameters listed above except ^{90}Sr, which will be analyzed only once a year. Offsite spring water will be sampled and analyzed as follows:

Number of Springs	Sample Frequency	Analyses
1	Semiannually	Gamma, enriched tritium. For first sampling event at any spring not previously sampled: gamma, plutonium, strontium, enriched tritium.
4	Annually	Gamma, enriched tritium. For first sampling event at any spring not previously sampled: gamma, plutonium, strontium, enriched tritium.
4	3 years	Gamma, enriched tritium.

A grab sample will be taken in small ponds in a manner that minimizes the volume of sediments in the samples. In larger ponds, three grab samples will be taken and composited for analysis. Spring water will be sampled using a hand-held container, and the flow rate, if practical (e.g., a functional flume or weir exists) of the spring at the time of the sampling may also be measured.

Surface water quality and spring flow rates are naturally variable and may be affected by natural and man-made conditions (e.g., construction/dirtwork, water withdrawal). Heavy or prolonged rains or snowmelt may dilute contaminants or may flush contaminants into surface waters from sediments. If possible, sampling will be performed during dry and nonwindy days. Sampling will not occur as scheduled if there is insufficient water at a site (e.g., the springs) to obtain a sample.

Water samples will not be filtered in the field. That portion of the sample not required for tritium analysis will be acidified to pH < 2. All solids and liquids in the samples requiring plutonium, strontium, and gamma spectrum analysis will be analyzed. Sample containers will be polyethylene or glass. The maximum holding time will be six months.

More detailed sampling and analysis methods and the analytical methods/protocols and quality assurance/quality control requirements for surface water samples are presented in Appendix B of the QAASP (Section 5.4.3). The methods were selected for their ability to detect the maximum number of parameters and meet the required detection limits for assessing if action levels are exceeded. The requirements are stated to ensure defensibility and integrity of the analytical data to DOE, peer reviewers, and regulatory agencies.

Actions Dependent on Results of Monitoring

If radionuclide concentrations in surface water samples exceed the action levels, then DOE will be advised of the elevated levels and additional evaluations or studies will be performed. These may include additional validation of laboratory analysis results, taking more water samples, or sampling of other related media (such as pond sediment) to confirm source levels. Study results will be documented in the ASER. If further analyses confirms that the action level has been exceeded, corrective actions will be proposed.

If the action levels are not exceeded, routine monitoring will continue and the concentrations will be documented in the ASER.

4.2.2 GROUNDWATER

The characteristics of regional and local groundwater regimes at the NTS and the sources of radionuclides with potential impacts on groundwater are presented in Chapter 2. The release of radionuclides from the underground test areas, their transport, and the human exposure pathways are also discussed in Chapter 2. Groundwater is monitored onsite and offsite to comply with several regulatory drivers described in Chapter 3. For a general overview of the UGTA subproject, its goals, and technical approach, the reader is directed to Bangerter (personal communication, 1998).

4.2.2.1 MONITORING OBJECTIVES

The objectives of the routine radiological monitoring program for groundwater include:

Water Supply Well Monitoring: Determine if onsite water supply wells are impacted from radionuclides originating from DOE operations on the NTS.

Permitted Facilities Monitoring: Determine if there are groundwater impacts from surface and shallow vadose zone sources of radionuclides on the NTS.

Aquifer Monitoring: Determine if groundwater at the NTS and its vicinity is further degraded as a result of the expansion of the radionuclide plumes associated with the underground test areas.

An additional objective specific to water-level monitoring is:

Provide water-level information to determine if wellbore and aquifer conditions may have changed, thus potentially altering sample representativeness.

To support these objectives, the monitoring program was designed based on professional judgment and a set of criteria established for the selection of monitoring wells, monitoring parameters, and action levels. All criteria are described in more detail in the QAASP (Appendix B).

4.2.2.2 CANDIDATE MONITORING WELLS/BOREHOLES

Virtually all existing wells that penetrate the water table at the NTS (onsite) and vicinity (offsite) were considered for this radiological monitoring program. A set of location and construction criteria was applied to yield a short list of potential monitoring wells. Many of these candidate wells were being sampled to measure water chemistry, quality, elevation, and use during the development of this radiological monitoring program. They include several networks of wells drilled and sampled to support various programs and objectives, and are described below.

Onsite Drinking Water Supply Wells

Groundwater is the only local source of drinking water at the NTS. The state permit for the NTS includes five drinking water supply systems which consist of ten wells which supply potable water. These wells are sampled to determine compliance with the drinking water standards, which include standards for radionuclides (BN, 1997). Other parameters (e.g., water elevations, usage) are also measured at these wells, to support program needs.

Each year, up to 12 supply wells were sampled quarterly; and 7 consumption points (tap water) monthly (pre-FY 1997) and quarterly (FY 1997). To comply with the Safe Drinking Water Act (SDWA) and the NRS, monitoring at NTS water supply wells will continue at a reduced frequency.

Wells Monitored for Water Levels and Water Usage

Well water levels have been monitored annually by the U.S. Geological Survey (USGS) at approximately 156 locations onsite and offsite (see Table 4.5). Data are analyzed for trends, impacts of water usage, and for the calibration input to groundwater flow models. The RREMP would integrate this data into the Environmental Management (EM) database. The existing water-level network is subject to change pending funding levels and a planned DQO evaluation.

Underground Test Area Program Wells

The FFACO between the state of Nevada, the DOE, and the DoD identifies 908 historical nuclear detonations that occurred in shafts or tunnels at the NTS. They are categorized into 878 CASs assigned to the UGTA program (DOE, 1994; FFACO, 1996). For UGTA sites, the FFACO requires DOE to establish specific sampling and monitoring to determine if releases (or potential releases) of pollutants and/or hazardous wastes migrate, or could potentially migrate. If such migration occurs, or could occur, then the constituents, their concentrations, and the nature and extent of the migration must be identified.

The 878 CASs are grouped into six CAUs that are geographically distinct, and which have different contaminant source, geologic, and hydrogeologic characteristics related to their location. These CAUs are Yucca Flat, Frenchman Flat, Western Pahute Mesa, Central Pahute Mesa, Rainier Mesa/Shoshone Mountain, and Climax Mine.

The objective of the UGTA program is to define boundaries around each CAU that establish zones of groundwater unsafe for domestic and municipal use. Regional groundwater modeling has been performed to provide an initial basis for assessing flowpaths from the CAUs (DOE, 1997). A second phase of the modeling and characterizations will refine the CAU boundaries through CAU-specific models with site-specific data. Wells will be established and monitored for a minimum of five years for model verifications. The closure activities under UGTA will be accomplished through the year 2014 (FFACO, 1996). Postclosure monitoring will continue for 50 years after closure of each CAU. The RREMP monitoring network described here is intended to comply with other laws and regulations in the interim during completion of the UGTA studies to assure protection of workers and the public. A brief summary of the UGTA subproject is presented in Bangerter (1998).

Hot Wells

Hot wells, also referred to as source-term characterization wells, are those used to sample groundwater from within or near the cavities produced by underground nuclear tests that were conducted below the water table. These groundwater samples are used to define the hydrologic source term (the type and concentration of radionuclides dissolved in groundwater, or potentially available to groundwater). Source term information fulfills the requirement in DOE Order 5400.1 to monitor the effects of DOE activities on the environment. This monitoring allows estimates to be made of the rate of migration from the underground nuclear tests.

Long-Term Hydrological Monitoring Program Wells

The LTHMP was established by DOE/NV in 1972 to determine whether or not radioactivity from underground nuclear tests has contaminated the groundwater in the vicinity of the test sites in Nevada and four other states. The design function of the LTHMP at the NTS has been to monitor groundwater and drinking water sources at the NTS and in all communities near the NTS. The onsite network in 1996 included 21 wells, while the offsite network included 12 wells, 9 springs, and 1 water body (BN, 1997). Water samples from these wells are analyzed quarterly for gamma emitters and semiannually for tritium. As presently envisioned, the RREMP would fully replace the LTHMP.

Permitted Facilities Wells

Five wells located at three facilities require routine groundwater monitoring under the terms of permits issued by the state of Nevada. These facilities are the RWMS-5, the Area 23 Infiltration Basin, and the Area 12 E Tunnel pond.

The Pit 3 Mixed Waste Disposal Unit located in the RWMS-5 is under Resource Conservation and Recovery Act (RCRA) Interim Status, in compliance with Title 40 CFR 265. A groundwater monitoring program, approved by the state of Nevada, was begun at this site in 1993 to detect leakage of hazardous constituents into the groundwater. The program established parameters and action levels and protocols for both detection and compliance monitoring. Three monitoring wells around the RWMS, drilled into the uppermost aquifer, are sampled routinely. A select set of indicator parameters are sampled as detection monitoring parameters, including tritium. If samples indicate that established action levels are exceeded, the facility is required to perform compliance monitoring and, if necessary, implement a corrective action program. Compliance monitoring requires at least semiannual monitoring of permitted parameters and constituents (see Appendix B).

To comply with the groundwater protection requirements of the state General Permit GNEV93001, a monitoring well was installed (SM-23-1) in 1996 for the Area 23 Infiltration Basin.

Water Pollution Control Permit NEV96021, in compliance with the provisions of the Federal Water Pollution Control Act and NRS, allows DOE/NV and the Defense Threat Reduction Agency (DTRA) to manage and operate a system for the treatment and disposal of waste-water discharging from the portal of E Tunnel in Area 12 of the NTS. The effluent from the portal is conveyed into six earthen dammed impoundments for disposal by means of infiltration. The groundwater at Well ER-12-1 will be sampled for RCRA Appendix IX parameters (Title 40 CFR 265) within six months of the issuance of the permit and every fifteenth month following.

4.2.2.3 WELLS SELECTED FOR THE ROUTINE RADIOLOGICAL MONITORING PROGRAM

The wells selected for inclusion in the radiological monitoring program are described below. They include all onsite potable and nonpotable water supply wells, most of the onsite UGTA wells and hot wells, permitted facility monitoring wells, and wells selected from among the existing NTS boreholes that can be retrofitted cost effectively to become monitoring wells. Offsite wells were selected from the drinking water supply wells in nearby communities and also from UGTA wells located in Oasis Valley. Separate criteria were established for the selection of monitoring wells to support each objective. These selection criteria are briefly summarized in this section. The number and type of onsite and offsite wells selected for inclusion in the groundwater radiological monitoring network are depicted in Figure 4.5 and the location of all selected onsite and offsite wells within the network, which meet all program monitoring objectives, are shown in Table 4.6. Appendix B, Attachments B1 through B3, provide wells which may in the future be required to support RREMP requirements.

Network of Wells to Support Objective 1 (Water Supply Monitoring)

Onsite potable and nonpotable water supply wells will continue to be used to support the proposed program. No new wells need to be added to the NTS water supply system because water usage at the NTS is not forecast to exceed the current system’s capacity in the near future. In addition to the water supply wells onsite, the network will include offsite water supply and existing monitoring wells selected based on the following criteria:

> Select point-of-use water supply wells downgradient of the NTS (in the general direction of regional groundwater flow). Current site knowledge eliminates the possibility of transport of radionuclides from source areas to wells upgradient of the NTS, or opposite to the general direction of regional groundwater flow.

Select wells close to the NTS boundary and in close proximity to the underground testing areas.

Give preference to community wells.

Give preference to high-yield, high-volume wells.

Give preference to wells with appropriate construction/condition.

Select wells where access is possible.

Consult with CTLP/Stakeholder programs to ensure that the concerns of local communities are addressed.

The onsite and offsite wells selected for monitoring to address the first program objective are listed in Table 4.6 and included in Figure 4.5.

Network of Wells to Support Objective 2 (Aquifer Monitoring)

From among existing wells and boreholes (called point-of-opportunity wells), those that are located downgradient of the CAUs and/or are in the regional aquifer are selected to become part of the proposed network of wells supporting the second program objective. Point-of-opportunity wells located within CAUs have been screened based on the following criteria for their inclusion in the proposed network:

Select point-of-opportunity wells downgradient of source areas.

Give preference to wells within 1,000 m (3,280 ft) of underground tests, which are located below or within two cavity radii of the water table.

Select wells accessing relevant hydrostratigraphic units within structural blocks having an upgradient source or sources.

Give priority to wells in those transmissive units which also contain most of the underground test locations.

Point-of-opportunity wells are existing wells which, according to the present level of understanding, appear to be at appropriate locations and completed in appropriate hydro-stratigraphic units. It is important to note that the RREMP is an interim program until the final CAU postclosure monitoring network can be designed and implemented.

The results of current and future modeling efforts by UGTA will be incorporated into the RREMP strategy. The RREMP therefore must be both opportunistic and flexible.

The network of onsite and offsite wells selected to address Objective 2 are listed in Table 4.6 and included in Figure 4.5.

Water-level measurements will be performed for each sampling event at all wells if practical (e.g., no downhole pump in well). Onsite and offsite wells which are monitored only for water levels are listed in Tables 4.7 and 4.5, respectively; and are shown in Figure 4.6. This existing network (for FY 1998) is subject to change with funding from other programs and pending a planned DQO process specific to water-level measurements.

Network of Wells to Support Objective 3 (Permitted Facilities Monitoring)

Three RCRA compliance wells in Area 5 (UE5 PW-1, UE5 PW-2, and UE5 PW-3) will be used to identify shallow (vadose zone) source contributions to groundwater. These wells will be monitored consistent with the requirements of RCRA Interim Status facility, per agreement between DOE/NV and the NDEP.

One permitted well in Area 23 (SM-23-1) will be monitored to identify surface water (sewage lagoon) source contributions to groundwater. This well will be monitored consistent with the requirements of state General Permit GNEV93001.

One permitted well in Area 12 (ER-12-1) will be monitored to identify surface water (E Tunnel containment pond) source contributions to groundwater. This well will be monitored consistent with the requirements of state General Permit NEV96021.

The five wells described above are listed in Table 4.6 and are included in Figure 4.5.

4.2.2.4 SAMPLING PARAMETERS AND ACTION LEVELS

Unless regulatory changes in permit conditions occur, the parameters and the action levels for the monitoring of the water supply wells and the permitted facilities on the NTS will remain the same. All wells will be sampled for tritium and additional parameters as shown in Table 4.8. The parameter of interest for the routine radiological monitoring of groundwater is tritium. The action level for tritium will be 10 percent of the drinking water standard. The standard method for tritium analysis can detect tritium at concentrations between 300 and 700 pCi/L and higher, and therefore may be used to satisfy program objectives. However, in practice, the RREMP may choose to use the enriched method which can detect tritium levels as low as 10 pCi/L.

Tap water samples are analyzed for gamma emitters, gross beta, tritium, ^{238}Pu, $^{239+240}$Pu, gross alpha (quarterly), and ^{90}Sr (annually). Samples from potable supply wells are analyzed for gamma emitters (gamma spectroscopy), gross alpha, gross beta, tritium (by enrichment method), $^{226+228}$Ra, ^{238}Pu, $^{239+240}$Pu, and ^{90}Sr. Samples from nonpotable wells are analyzed for gamma emitters (gamma spectroscopy), gross alpha, gross beta, tritium, ^{238}Pu, $^{239+240}$Pu, and ^{90}Sr (annually).

Other water parameters (e.g., pH, specific conductivity, etc.) will be measured at selected wells at the same time water samples for radiological analysis are collected. For example, at new monitoring wells that do not have previously established baseline data on water chemistry, water chemistry data will be collected during the first year of sampling. Also, at selected wells, it may be necessary to measure parameters to confirm certain assumptions of radionuclide migration models for groundwater (e.g., confirm the existence of colloidal transport). These other parameters are shown in Table 4.8 (see Type IV Analysis).

4.2.2.5 SAMPLING FREQUENCY

Sampling frequency for the wells in the proposed network will differ. Water supply wells and wells within close proximity of source areas (UGTAs) will be sampled more frequently, and wells without established background data will be sampled more frequently for one year. Some sampling events at water supply wells may be skipped, with program management approval, if the well is not being used. Sampling frequencies of the wells are summarized in Table 4.8. Table 4.6 shows the proposed type of analysis and sample frequency for each well. The analysis and sample frequency schedule for the NTS drinking water system endpoints is presented in Table 4.9.

4.2.3 DRINKING WATER CONSUMPTION ENDPOINTS

The drinking water network at the NTS consists of five separate systems, with seven consumption endpoints (BN, 1997). Ten potable supply wells feed the five drinking water systems (Table 4.9). As a check on any effect the water distribution system might have on water quality, the seven water system endpoints (tap water) were sampled on a monthly (pre-FY 1997) or quarterly (FY 1997) basis. No test-related radionuclides have been detected to date.

To support RREMP objectives and to demonstrate compliance with relevant regulations (e.g., SDWA, DOE Order 5400.5, and NRS 445A.361), the seven drinking water consumption endpoints will continue to be sampled according to the schedule presented in Table 4.9. Distribution systems located within, or traversing, the historical testing areas will be sampled more frequently (quarterly), while the other systems will be sampled on an annual basis. The tap water samples will be analyzed annually for gamma emitters, gross alpha, gross beta, tritium (enriched method), ^{238}Pu, $^{239+240}$Pu, and ^{90}Sr.

4.3 SOIL MONITORING

Radiological monitoring of the soil media includes monitoring surface soils and the vadose or unsaturated zone of geologic formations. Because these two aspects of the soil media are characterized by different radionuclides of concern and different migration pathways, they are presented separately below.

4.3.1 SURFACE SOIL

4.3.1.1 MONITORING OBJECTIVES

There are numerous contaminated surface soil sites on the NTS (Figure 2.5) that provide a source of radioactive material to air, water, plants, and animals. The only exposure pathway considered for surface soil monitoring is direct exposure to external radiation from the soil surface. Direct ingestion of surface soils is considered unlikely in the case of humans, and other pathways to humans, plants, and animals are addressed in the monitoring plans for air (Section 4.1), surface water (Section 4.3), and biota (Section 4.4). The health threat to NTS workers and the general public from direct exposure to external radiation from surface soils is negligible because of active institutional control. This control consists of delineating the boundaries of all contaminated surface soil sites on and off the NTS, obtaining or maintaining inventories of radionuclide levels within these sites, and restricting unauthorized access into them.

Accurate descriptions of the amount and distribution of radioactivity in surface soil at the NTS are required by other media in the environmental monitoring program. The air monitoring program uses these source descriptions in numerical transport models to evaluate radionuclide transport through air to the offsite public. These descriptions are also used to design and implement surface water and biota monitoring. In addition, monitoring the boundary of the contaminated soil sites on the TTR is needed to verify stabilization of soils following remediation. Existing sources of information include aerial surveys, demarcation surveys, reports from the RIDP, and historic thermoluminescent dosimeter (TLD) data (McArthur, 1991; DOE, 1995; BN, 1996). Because much information has been gathered over the past 30 years on the amount of radionuclides present at contaminated soil sites, such efforts will not be pursued by this monitoring program.

The objectives of onsite surface soil monitoring are to determine if the location or areal extent of the contaminated surface soils at the NTS and TTR are changing and, if they are, to modify the inputs to airborne radionuclide exposure models and the design elements of surface water and biota monitoring accordingly.

High-volume air samplers are located offsite to measure airborne radioactivity attributable to onsite sources. Offsite surface soil monitoring is driven by the need to assess the possibility that offsite sources in the vicinity of the air samplers may be contributing to the air concentrations which are measured.

4.3.1.2 SAMPLING AND ANALYSIS DESIGN

Ongoing monitoring of the boundaries of the contaminated soil sites will be conducted at the NTS as part of site demarcation surveys. The information required to meet the objectives of the Environmental Monitoring Program is the location of site boundaries consistent with the requirements of Title 10 CFR 835, Appendix D. Sampling and analysis will be conducted according to plans developed by the demarcation project. The schedule proposed for the demarcation surveys as of December 1997 provides for a subset of the sites to be surveyed every year on a timetable where each site will be surveyed every five years. No action levels will be set for boundary location. Updated boundary locations will be incorporated in the dose assessment model as they become available.

At offsite locations, each high-volume air sampling location will be assessed for surficial plutonium deposition using *in situ* surveys (FIDLER) and representative (composite) surface soil sampling and analysis for plutonium.

4.3.2 VADOSE ZONE MONITORING

The vadose zone is being monitored at two general types of sites on the NTS: two RWMSs and Industrial Sites which are identified for corrective action under the FFACO. These two types of sites are managed under two DOE/NV EM programs, the Waste Management (WM) program and the ER program. Once closure has been completed, long-term monitoring of both types of sites will become the responsibility of the DOE/NV Environmental Protection Division.

The FFACO, an agreement between the DOE and the NDEP, identifies 2,400 CASs located at the NTS and TTR that comprise the DOE Industrial Sites Subproject. Monitoring is required at only a small number of these sites. The need to perform corrective action at these sites is driven by RCRA regulations; however, most of these closures will be completed with processes outlined in the FFACO. These sites comprise a variety of waste units including landfills, waste ponds, injection wells, leachfields, decontamination and decommissioning facilities, and ordnance sites. They are typically small in areal extent (from several hundred square feet up to several acres in area) and are typically shallow in depth (typically up to 30 m [100 ft]), but can extend to a depth greater than 91 m (300 ft) in some instances. The type of waste at these sites include petroleum hydrocarbons, sanitary waste, RCRA heavy metals, polychlorinated biphenyls, ordnance, and low-level radioactive waste.

Currently, two Industrial Sites require vadose zone monitoring: CAU 91, the Area 23 Hazardous Waste Trenches; and CAU 112, the U-3fi Waste Unit located in Area 3.

The specific monitoring requirements for each closure are determined by DOE/NDEP on a case-by-case basis and are based on the technical requirements defined by site characterization studies. All RCRA closures follow prescribed RCRA regulations regarding monitoring and must have either groundwater monitoring or a groundwater monitoring waiver. The regulatory agency may require a vadose zone monitoring system. The monitoring method is determined based onsite characteristics, cost, and the performance criteria mutually agreed upon with the regulatory agency.

The two large RWMSs (RWMS-5 and RWMS-3), operated by the Waste Management Division (WMD), are designed and operated for disposal of DOE low-level waste (LLW). All waste disposal in RWMS-5 has occurred in a 37-hectare (ha) (92-acre [ac]) portion of the site referred to as the Low-Level Waste Management Unit (LLWMU). The LLWMU consists of 22 landfill cells (pits and trenches) and 13 GCD boreholes. GCD boreholes are no longer active. Pit 3 is the only active mixed waste disposal unit. All other active units contain low-level radioactive waste. Of the 22 landfill cells, 3 pits and 11 trenches have been closed. The remaining three pits and five trenches are open. Pits and trenches range in depth from 4.6 to 15 m (15 to 48 ft). Disposal consists of placing LLW in various containers in the unlined pits and trenches. Soil backfill is pushed over the containers in a single lift as rows of containers reach approximately 1.2 m (4 ft) below original grade. A detailed description of the facilities at RWMS-5 is contained in Shott *et al*. (1997b).

The seven craters within RWMS-3 at the time of formation, ranged from 122 to 178 m (400 to 580 ft) in diameter and from 14 to 32 m (46 to 105 ft) in depth (Plannerer, 1996). Disposal in the U-3ax crater began in the late 1960s. Disposal began in U-3bl in 1984. Waste forms consisted primarily of contaminated soil and scrap metal, with some construction debris, equipment, and containerized waste. The U-3ax/bl disposal unit is currently covered with a minimum of 1.5 m (5 ft) of uncontaminated backfill that serves as a temporary cover (DOE, 1989). Disposal in the combined unit U-3ah/at began in 1988. Disposal cell U-3ah/at is currently being used for disposal of bulk, low-level radioactive waste from the NTS and approved offsite generators (DOE, 1996a). Crater U-3bh was used for disposal of contaminated soils from the TTR in 1997 and remains open. The remaining two craters are not in use.

4.3.2.1 MONITORING OBJECTIVES

This section describes objectives of vadose zone monitoring at both ER and RWMS sites, identifies similarities and differences between the programmatic approaches to vadose zone monitoring, and describes the standard elements of a vadose zone monitoring strategy. A QAASP for radiological monitoring of the vadose zone has not been produced. Design of detailed monitoring plans for individual sites will be completed independently by ER and WM programs.

Industrial Sites

Design of vadose zone monitoring at closed Industrial Sites is tailored for each site's unique combination of location, transport characteristics, and constituents of concern (COCs). Monitoring is typically done for sites closed in place. Following characterization and appropriate remediation, the sites are closed with the assurance that hazardous and/or radiological materials will not be released to the environment. In general, for sites closed in place, the objectives of vadose zone monitoring, when required, is to provide surveillance of the closed sites to verify performance of the closure and to permit expeditious corrective action should it become necessary.

Radioactive Waste Management Sites

Design of vadose zone monitoring at the two RWMSs includes a number of programmatic objectives associated with daily operations of the site and planning for closure. In general, at the RWMS sites, the objectives of the vadose zone monitoring is to assure compliance with relevant DOE Orders and regulations, and to provide early warning of movement of contaminants toward the groundwater. Monitoring objectives at the RWMS sites are:

Confirmation of Performance Assessment: Data from vadose zone monitoring will be used to verify and potentially reduce the uncertainty of assumptions of the performance assessment calculations and to test the validity of the conceptual model of the vadose zone developed for the performance assessment.

Detect Changing Trends in Performance: Provide data to detect changing trends in performance sufficiently in advance to apply corrective action if required.

Demonstrate Compliance with Applicable DOE Orders and Environmental Standards.

4.3.2.2 MONITORING PLAN ELEMENTS

Design of a monitoring plan requires identification of both the environmental pathways by which exposure occurs and the COCs. Site characterization information is then used to estimate water flow and migration in the vadose zone. Modeling potential release scenarios provides the necessary information for decisions regarding important monitoring plan elements. These elements include parameters to be monitored, methods, frequency of monitoring, and location of monitoring points.

Release Scenarios

Potential transport processes from sources in the shallow vadose zone include advection and diffusion of gaseous contaminants, upward advection and diffusion of solutes, plant uptake, and bioturbation due to plant and animal activity. The result of these processes is the accumulation of radionuclides in the surface soil and eventual release into the atmosphere. In the region below the source, and for sources at greater depths, gas- and liquid-phase advection and diffusion occur. Transport is attenuated by adsorption, precipitation, biodegradation, decay, and other processes.

Parameters

Monitoring parameters can be either direct or indirect. Indirect monitoring is the measurement of parameters that may indicate that radionuclide migration is occurring, but does not provide direct evidence of migration. Direct monitoring is the sampling and analysis of media to detect the presence and concentration of radionuclides. Examples of indirect monitoring parameters in the liquid phase are water content, matric potential, and analysis for surrogate chemicals. Examples of direct monitoring in all phases are sampling of pore liquids, soil gas sampling, and matrix sampling.

Methods

Methods for *in situ* measurement of water content include neutron moderation (Gardner, 1986), time-domain reflectometry (White and Zegelin, 1995), and frequency domain methods. Thermocouple psychrometers (Rawlins and Campbell, 1986) and heat dissipation sensors (Campbell and Gee, 1986) are examples of methods used to measure water potential. Numerous methods have been developed for obtaining matrix samples from the vadose zone for laboratory analysis (Dorrance *et al*., 1995). These methods include various types of auger, tube, barrel, and bulk samplers. While soil sampling may be an appropriate response to exceeding an action level set for water content or water potential, this method is not suitable for routine vadose zone monitoring because matrix sampling is destructive and not repeatable. There are severe limitations associated with direct measurement of radionuclides in a liquid phase in the vadose zone at the NTS, including that direct measurement requires higher soil moisture contents and lower water potentials than those observed or predicted at the NTS. Soil gas provides another method through which direct measurement of volatile radionuclides in a medium can occur. There are now numerous methods available for the collection of soil gas samples from the subsurface (Stephens, 1996); however, interpretation of the measured concentrations must take into account the qualitative aspects of this approach (Ullom, 1995). Further consideration in selection of methods are the longevity of the sensor, probe, porous sampling cup, or access tube in the alluvium; long-term stability; and calibration.

Monitoring Frequency

The time scales of the transport processes of interest will influence monitoring frequency. These time scales are determined by analysis of the release scenarios discussed above.

Location of Monitoring Points

Instrument location at a closed Industrial Site is influenced by aspects of the location, size, COCs, and their concentrations. The number and location of monitoring points at the RWMSs are based on the performance assessment. They are selected to provide environmental data required to characterize and define trends in environmental parameters and to confirm that conceptual models and media characteristics used in the performance assessment model are accurate.

4.3.2.3 ACTION LEVELS

Action levels are parameter limits which, when reached, trigger a response. Typical responses may include resampling, increasing sampling frequency, controlling runoff to reduce the source of increased infiltration, repair of cover, soil solution sampling, soil matrix sampling, or adjusting conceptual models. Action levels for vadose zone monitoring at the NTS are determined by each program's monitoring plan and are dependent on the goals of the program. Action levels and responses for postclosure monitoring at Industrial Sites are determined through negotiation with the NDEP on an individual site basis and are based on expected site performance criteria. Action levels and responses at the RWMSs will be established by DOE based on expected site performance determined by modeling of exposure pathways.

4.3.2.4 SAMPLING AND ANALYSIS DESIGN

Design of site-specific monitoring plans for RWMS and closed Industrial Sites will be completed as required by both site-specific and programmatic issues. Monitoring plans will be developed using a consistent process and will result in core, defensible monitoring plans adapted to site-specific concerns. Core elements of consistency will be derived as a result of common use of three elements as the central principles of the monitoring plans: (1) the hydrologic conceptual model developed for RWMSs-3 and -5 Performance Assessments, (2) general principles of vadose zone monitoring presented above, and (3) a monitoring plan checklist developed for alluvial sites found in Appendix F.

4.4 BIOTA MONITORING

This section briefly describes the objectives and design elements of a radiological monitoring plan for both plants and animals on and off the NTS. The monitoring objectives, action levels, data collection designs, and monitoring decisions are similar for both media and are therefore presented together in this section. A description of the sampling design for offsite plant and animal monitoring is also provided.

4.4.1 MONITORING OBJECTIVES FOR BIOTA

Air, surface soil, and surface water on the NTS were contaminated with long-lived man-made radionuclides by atmospheric, Plowshare, safety shot, rocket, and some underground tests that vented radioactive material to the surface. These media provide a source of contamination to NTS plants and animals and to the offsite public. Historical radionuclide studies on the NTS focused on man-made transuranics and showed declining concentrations in plants and animals over time (DOE, 1992), although some plant and animal samples still contain measurable levels (EG&G/EM, 1993; EPA, 1996). These past studies indicate that significant radionuclide damage to plants and animals on the NTS would occur only during atmospheric nuclear testing. Given the current DOE project and land use policy, it is unlikely that NTS radionuclide contamination poses a significant threat to biota, although data to confirm this conclusion have yet to be taken.

Past studies, although limited in scope and area, indicate that radionuclides in NTS plants and animals posed no significant threat of radiation exposure to the offsite public. Current NTS land use precludes the harvest of plants or plant parts (e.g., pine nuts, wolf berries) for direct consumption by humans. Therefore, the primary exposure pathway of radionuclides in NTS plants to the public is through ingestion of game animals. Game animals (e.g., mourning doves, chukar) may eat contaminated plants, seeds, or soil or drink contaminated water on the NTS and then travel offsite where they are subsequently hunted by the public for food. A secondary human exposure pathway for a particular radionuclide, tritium, is through inhalation of HTO transpired by contaminated plants. In a scoping investigation, inspired by the observations that (1) desert shrubs get a portion of their water from groundwater that slowly diffuses up toward their root zone and (2) that analyses of feral horse feces showed activities too high to be due to inhalation of NTS air, plant samples were collected from many areas of the NTS for measurement of their tritium content (Hunter, 1997). In all, about 629 plants or various types were collected and the tritium content in stem water was measured. Plants in known contaminated areas contained more tritium in stem water than plants from nearby areas. A small sample of the data, as shown below, indicated the differences found.

Source Area	Median Tritium Concentration – pCi/L of Plant Water: Plants on Source	Plants Away from Source
SEDAN	3.65×10^7	850
CABRIOLET	2,900	260
Rainier Mesa	790	110
Tunnel Ponds	150	140
Mud Plant	6,900	84

Similar results were found in many other areas of the NTS and so would contribute tritium to the ambient air. More data from this investigation is shown in Attachment C-2 to Appendix C. The expected public dosage via these pathways from NTS biota are well below established dose limits.

Offsite plants and animals, namely crops and livestock in neighboring communities, have also been monitored for years to document possible radionuclide exposure to the public (EPA, 1978a,b; EPA, 1996). The only possible current pathway for radiation exposure through crops is their uptake of radionuclides from soil which was contaminated during past atmospheric tests. There are several communities to the north and east of the NTS (e.g., Rachel, Alamo, Hiko) that have received radioactive fallout in the past from these tests. Recent radioanalysis of selected fruits and vegetables from these communities has shown levels of ^{3}H, ^{90}Sr, and $^{239+240}Pu$ near or below detection limits (EPA, 1996). Livestock or game animals within the same downwind fallout areas could ingest contaminated forage and then be consumed by humans. ^{90}Sr levels in the bones of deer, cattle, and bighorn sheep sampled in 1993 off the NTS were above detection limits, but have consistently decreased in samples since the early 1960s since cessation of aboveground testing (EPA, 1996). The edible portions of these offsite animals historically contain nondetectable levels of radionuclides. However, ^{90}Sr levels in milk from pasture-fed cows sampled from neighboring Nevada ranches have been periodically measured at levels above detection limits (EPA, 1996).

Given the assumption that there exists no significant risk to plants, animals, or the public through the food chain from radionuclide contamination, it is still expedient to include biota samples within the framework of this RREMP for the following reasons.

Some level of biota monitoring is needed to comply with DOE Order 5400.1. This Order states that environmental surveillance shall be conducted to monitor the effects, if any, of DOE activities on onsite and offsite environmental and natural resources. The surveillance should be designed to characterize or define trends in the physical, chemical, and biological condition of environmental media. The DOE regulatory guide to be followed to comply with DOE Order 5400.1 (DOE/EH-0173T, "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance" [DOE, 1991]) states that the minimum criteria for radiological surveillance is routine sampling and analysis of all environmental media that might lead to a total measurable annual dose of site origin at the site boundary that exceeds 5 mrem EDE. The minimum criteria for periodic confirmation is the sampling and analysis, at least every five years, of environmental media to confirm the low dose levels if the projected annual EDE of site origin is less than or equal to 0.1 mrem. The purpose of the biota monitoring component of the RREMP is to periodically sample and analyze those plants and animals expected to be the most contaminated so as to confirm their very low contribution to the total projected doses to the public.

Biota monitoring data is needed to validate the integrity of land buffers. DOE/NV is planning to issue a land-use planning goal to provide a buffer around site operations to ensure public safety and prevent public exposure to radiation. Monitoring of selected onsite biota provides data on radionuclide transport beyond contaminated areas via mobile organisms. Also, monitoring of selected offsite foodstuffs will document public exposures.

Biota data will be needed to address current and future land-use issues. The levels of radiological contamination of both the natural and man-made resources on the NTS is needed for current land-use decisions such as project siting. These data will also be needed when both land and biological resource management may shift from DOE to another agency or party in the future.

4.4.2 MONITORING SITES FOR BIOTA

4.4.2.1 NTS CONTAMINATED AND CONTROL SITES

The study designs for radiological monitoring of NTS plants and animals focus on sampling those sites having the highest known concentrations of radionuclides in other media. The location and boundaries of these sites will be determined from existing radiological surveys. The intent is to concentrate monitoring efforts at sites where the likelihood for radionuclides to enter plants and game animals is the highest. It is then expected that consumption of game animals from these sites would create the highest doses to humans, as compared to game animals collected elsewhere on the NTS. One monitoring site was selected from each of the following types of contaminated areas on the NTS, including:

Runoff areas or containment ponds associated with underground or tunnel test areas. These sites have the highest reported levels of radionuclides on the NTS, usually a result of contaminated surface water. The candidate site is the E Tunnel ponds below Rainier Mesa.

Plowshare sites in alluvial fill at lower elevations with high surface contamination. Subsurface nuclear detonations at these sites have distributed contaminants over a wide area, usually in the lowest precipitation areas of the NTS. The candidate site is SEDAN Crater in Yucca Flat.

Plowshare sites in bedrock or rocky fill at higher elevations with high surface contamination. Subsurface nuclear detonations at these sites distributed contaminants over a wide area, usually in the highest precipitation areas of the NTS. The candidate site is PALANQUIN.

Atmospheric test areas. These sites have highly disturbed soils due to past removal of topsoil from historical cleanup efforts and sterilization of soils from heat and radiation during testing. The same areas were often used for multiple nuclear tests. The candidate site is T2 in Yucca Flat.

Aboveground safety shot sites. These areas are typified by remaining radioactive soil contamination, primarily in the form of plutonium and uranium. The candidate site is Plutonium Valley (Area 11).

A control site for each contaminated site will be selected and will have similar biological and physical features, but will have no history of radionuclide contamination from DOE activities above worldwide levels of fallout. Measurements from the control sites will be used to document radionuclide levels in biota from areas believed to be uncontaminated by past and ongoing DOE activities and representative of background levels. Control sites will be located at least 5 km (3 mi) away from any contaminated site. This distance was selected to help ensure that small game species (e.g., rabbits, mourning doves) sampled at a control site are not obtaining food or water from an adjacent contaminated site. Four kilometers (2.5 mi) is the estimated maximum distance that doves routinely fly for water or food (Howe and Flake, 1988). Contaminated monitoring sites and control areas are shown in Figure 4.1.

Only one of the five contaminated NTS sites and its respective control site will be sampled each year. Therefore, each contaminated site will be sampled only once every five years. DOE guidance specifies that environmental surveillance measurements may be collected periodically, but should be collected at least every five years to confirm dose levels that are below action levels (DOE, 1991).

4.4.2.2 NTS CHUKAR SAMPLING SITES

In the past, the Nevada Division of Wildlife (NDOW) has requested, and has been granted, permission to trap and remove chukar from the NTS. The chukar are then released in areas open to public hunting. Chukar are trapped by the NDOW at one to three of the numerous natural springs on the NTS. Chukar trapped at these springs are not expected to be contaminated, but they will be sampled from these springs for radiological analysis on a routine basis. One spring site will be sampled annually. Possible locations from which chukar will be monitored are shown in Figure 4.1.

4.4.2.3 OFFSITE MONITORING SITES

Offsite monitoring of biota will be restricted to foodstuffs that are likely to be contaminated based on current offsite transport models for airborne radiation. Therefore, samples will include only milk from pasture-fed cows raised downwind to the east and north of the NTS, within the fallout areas resulting from past atmospheric testing. Milk from one or more cows will be collected from one downwind community (e.g., Mesquite, Caliente, Alamo), and from one upwind community (e.g., Amargosa Valley, Pahrump) to the west and south of the NTS. No other agricultural product from any other site off the NTS will be monitored. Offiste biota monitoring will be performed in communities indicated on Figure 4.2.

4.4.3 PARAMETERS AND ACTION LEVELS

The radionuclides to be monitored in NTS biota include tritium, ^{137}Cs, ^{90}Sr, and $^{239+240}Pu$. The radionuclide to be monitored in offsite-sampled milk will be ^{90}Sr. A gamma scan will also be performed on all biota samples.

There currently are no regulatory limits for radionuclide concentrations in native plants and terrestrial animals on the NTS. Past NTS studies indicate that significant damage to plants from radiation is unlikely to occur under current land-use practices and DOE activities, even at the most contaminated NTS sites (Wallace and Romney, 1972; DOE, 1992). Therefore, the establishment of an action level aimed at preventing damage to NTS vegetation was not necessary. In the case of animals, DOE Order 5400.5 sets an exposure limit only for aquatic animals of 1 R/day, but this limit has no practical application on the NTS given the environmental setting, contamination sources, and migration pathways of radionuclides on the site. Few studies have been done to establish standard acceptable doses for animals. There is evidence from the few studies that have been done that wildlife may tolerate higher radiation doses than humans (O'Farrell and Emery, 1976).

The action levels for radionuclide concentrations in onsite plants and animals will be established based on their contribution to human radionuclide doses. The action levels will be those specific concentrations of each monitored radionuclide per milliliter of liquid or per gram of dry ash of biotic material which leads (through the food chain) to an annual EDE in humans of 5 mrem. These action levels are based on a MEI dose of 5 mrem EDE if it were sustained for one year and are recommended by the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE, 1992).

These action levels will be calculated by a qualified health physicist and animal ecologist using an accepted human pathway exposure model. All parameters and assumptions used in the model will be determined prior to sampling and described in the QAASP (Appendix C). Separate action levels will be computed for each radionuclide being monitored and for each unique sample type (i.e., each plant or animal species). Once these action levels have been established, they will aid in determining the number and size of samples to be collected at contaminated and control sites.

No action levels, presented as differences of a certain magnitude between mean radionuclide levels in samples from contaminated and control sites, were established. The intent of the monitoring program is not to prove statistically that contaminated site samples have significantly higher levels of radionuclides than noncontaminated site samples. Measurements from control sites are expected to be lower than those from contaminated sites, representative of worldwide fallout, and well below the action levels described above. Control site data collected annually will be used to document long-term trends in background contamination and assure the public that radionuclides are behaving as expected in the environment.

The action level for offsite milk samples will be set at the analytical detection limit for ^{90}Sr.

4.4.4 SAMPLING AND ANALYSIS DESIGN

4.4.4.1 PLANTS

At contaminated NTS sites, samples will be collected from the most contaminated vegetated areas known within the site. Samples at each contaminated and control site will be collected from two or more plant species. The species selected will represent the most dominant plant life forms present (e.g., trees, shrubs, herbs, or grasses). Plant parts will be collected that represent new growth over the past year (annual biomass). Plant parts will include aerial stems, leaves, and flowers or seeds, especially parts known to accumulate radionuclides. Roots will not be sampled because they may contain radionuclides from the soil adhering to the root surface in addition to radionuclides absorbed into the roots. If no new plant growth occurred within the past year, then plant parts representing the past five years' growth will be collected. Sampling will occur during the summer when tritium levels in vegetation are expected to be highest (Hunter, 1997).

Changes in the plant sampling design may occur due to environmental conditions. During drought years when precipitation is insufficient to produce plant matter of selected sample species, alternate plant species (e.g., annuals) will be sampled if possible, or sampling will be deferred to other sites or years with sufficient precipitation. Also, the number of plant species available to sample may be restricted at disturbed sites due to harsh conditions (e.g., lack of topsoil, soil compaction, low nutrients, extreme soil temperatures) or due to active vegetation management at some sites (e.g., blading of soil caps over waste pits at the RWMS). Laboratory analyses of samples will conform to standards established by DOE guidance (DOE, 1991).

4.4.4.2 ANIMALS

Three criteria were used to determine which animal species on the NTS to sample. The first was that the species should have a high probability of entering the human food chain. Candidate animals based on this criteria included browsing mammals (e.g., mule deer, desert bighorn sheep, pronghorn antelope, and rabbits) and game birds (e.g., mourning doves and waterfowl). They should also have a small home range which overlaps a contaminated site and, as a result, should have high radionuclide body burdens representative of exposure to contaminated soil, air, water, or plants at the contaminated site. Thirdly, the selected species should be sufficiently abundant at a site to acquire an adequate tissue sample for laboratory analysis. DOE guidance also states that: "Wildlife that is relatively rare locally should not be taken as environmental samples" (DOE, 1991). These last two criteria limited the candidate game animals on the NTS to mourning doves, chukar, and rabbits.

At each contaminated site and its respective control site, mourning doves will be trapped and rabbits will be shot. At one spring site each year, chukar will be trapped. Edible tissues of each game animal will be analyzed for tritium, ^{137}Cs, and $^{239+240}Pu$, and selected bone samples will be analyzed for ^{90}Sr. Precautions will be taken to ensure that meat samples are not contaminated by soil or other contaminated material on the feathers or fur or in the feces of the animals.

Laboratory analyses of samples will conform to standards established by DOE guidance documents (DOE, 1991).

Offsite milk from one downwind and one upwind dairy or private ranch will be sampled and analyzed annually during July. A one-gallon sample from one or more pasture-fed cows and/or goats from each of two sample sites will be collected and analyzed for gamma emitters and $^{89+90}$Sr.

4.4.5 ACTIONS DEPENDENT ON RESULTS OF BIOTA MONITORING

If mean concentrations of tritium, ^{137}Cs, ^{90}Sr, or $^{239+240}$ Pu are below the action levels in plant and animal samples at a contaminated and control site on the NTS and at the two offsite milk sampling stations, the concentrations will be documented in the ASER. No additional evaluations, assessments, or special studies at the sites will be performed. Environmental surveillance measurements from plants and animals at the NTS contaminated site and its control site will continue at a frequency of at least once every five years to confirm the low contamination levels. Offsite milk samples will continue to be collected annually.

If mean concentrations of tritium, ^{137}Cs, ^{90}Sr, or $^{239+240}$ Pu are equal to or above the action levels in either plants, animals, or cow's milk at a sample site, then DOE will be advised of the elevated levels, and additional sampling and analysis will be performed. These may include additional validation of laboratory analysis results, further statistical sampling of plants and animals, further biota sampling to determine the spatial or temporal boundaries of the problem area, or sampling of other related media to confirm source levels and document trends. Additional plant or animal species may be sampled to better define radionuclide sources and human exposure pathways. All study results will be documented in the ASER, and monitoring at the sample site and its control site will continue at an increased frequency of once a year for onsite locations.

4.5 DIRECT RADIATION MONITORING

Direct radiation monitoring is used to detect radiation exposures caused by sources that emit X rays, gamma rays, charged particles, and/or neutrons. Such monitoring can be done in real time by use of appropriate survey meters or by pressurized ion chambers (PICs) to obtain exposure rate, and by various types of solid-state dosimeters to obtain total exposure. For this RREMP, TLDs and PICs will be used.

4.5.1 MONITORING OBJECTIVE

Onsite TLD and PIC Monitoring

The objective of onsite TLD and PIC monitoring is to assess the state of the NTS's external radiation environment, detect changes in that environment, and measure gamma radiation levels near and in contaminated areas on the NTS. The onsite monitoring program will be used for trend analysis, in conjunction with flyover data and demarcation studies, and to comply with DOE Orders 5400.1, 5400.5, and 5820.2A, and the guidance in DOE/EH-0713T and DOE/LLW-13Tg. PICs will provide measurements of background radiation using a method independent of the TLD system. These measurements will be used to evaluate the accuracy and precision of the TLD system (DOE 1988a,b; 1990; 1991).

Offsite TLD and PIC Monitoring

The objectives of these networks are to detect and monitor trends in ambient gamma radiation levels that may be affected by onsite operations, environmental transport, or fallout from atmospheric tests, and to address stakeholder concerns. Offsite stations are sited in communities near the NTS and in the downwind direction (related to previous fallout). The potential for release of radioactivity from the NTS due to onsite operations, natural occurrences, or transportation accidents are among the concerns voiced by stakeholders. Offsite TLDs measure the present ambient radiation levels at selected locations and can be used to detect trends in these levels. In addition to TLDs, a network of PICs, which measure instantaneous exposure rate, is located at selected stations. PICs give an immediate indication of exposure rates that exceed background so that prompt investigation and documentation of the cause of the high background readings can occur.

Other Facility Direct Radiation Monitoring

Monitoring for direct radiation is performed at public access boundaries of BN-managed facilities off the NTS which have radiation-generating devices or radiation sources that could cause radiation levels to the public at or near the site boundary. This includes monitoring for X rays, gamma rays, and neutrons. The monitoring objectives at these facilities are to (1) verify each project's use of safety features or procedures to limit area radiation; (2) collect data for use in calculating the impact to human health in the event of safety feature failure or procedural violation; and (3) verify compliance with current, applicable regulations.

4.5.2 MONITORING PARAMETERS

Photons from gamma radiation and X rays with energies of approximately 60 keV and above will be measured by TLDs and PICs. In areas where neutron radiation may be present, track etch neutron dosimeters (TENDs) will be used to measure neutrons in the energy range from 80 keV to 4 MeV.

4.5.3 ACTION LEVELS

Onsite and Offsite Monitoring

TLDs and PICs measure ambient gamma radiation levels. Changes with time in ambient radiation levels at a location normally do not occur naturally. Therefore, any statistically significant change in gamma radiation levels with time at any station will be considered an action level. Statistical analysis will be designed to identify changes in TLD readings which may be due to system errors, such as calibration or instrument problems, and changes at individual locations, which may be due to a real change in radiation levels or due to a problem with an individual TLD.

Other Facility Monitoring

Title 10 CFR 835.402 specifies that for the purpose of monitoring individual exposures to external radiation, personnel dosimetry shall be provided to and used by members of the public likely to receive a dose in excess of 50 mrem/yr from external sources. This external exposure limit will be used as the action level. Factors such as occupancy time and ambient background radiation levels will be taken into consideration when estimating the external exposure to a member of the public from other than background radiation.

4.5.4 SAMPLING AND ANALYSIS DESIGN

All onsite and offsite TLDs will be placed 1 ± 0.3 m (28 to 51 in) above ground surface in a manner that will minimize distortion of the radiation field (i.e., away from large or dense objects). These guidelines for TLD placement are in accordance with DOE guidance (DOE, 1991) and American National Standards Institute (ANSI) standards (ANSI, 1996). The selection of the onsite and offsite TLD stations are described in the following subsections.

4.5.4.1 SELECTION OF ONSITE TLD AND PIC STATIONS

Onsite TLD posting stations for four categories are discussed below. The four categories are Environmental stations, Waste Management Site stations, Background stations, and Historical stations. The purpose of Environmental stations is to demonstrate compliance/noncompliance with DOE Order 5400.5 requirements, and to monitor trends in direct radiation levels in areas of soil contamination and relate these trends to predictions, flyover data, and demarcation data. The data from environmental TLDs may also be used during future facility siting decisions and by Environment, Safety, and Health (ES&H) to determine Title 10 CFR 835 compliance. Waste Management Site stations are to comply with DOE Order 5820.2A to monitor the effect of waste management operations on the radiation levels at and near the perimeter of waste management sites. Background stations are to measure the ambient radiation in areas unaffected by operations on the NTS. Background stations are at least 10 km (6 mi) from the nearest area with elevated radiations levels due to man-made use of new readers and/or TLDs is implemented. The radiation level at some historical stations is distorted because of man-made structures; however, because the purpose of historical TLDs is to demonstrate consistent ambient radiation levels with time, these locations are acceptable as historical locations, provided changes are not made to the structures which may affect the ambient background radiation levels.

TLD Posting Station Site-Selection Criteria

– ***Environmental Stations:*** Environmental TLDs are to be posted in and around areas where the radiation levels are elevated because of soil contamination. Because of the access restrictions to soil contamination areas where the contamination is removable, the stations will be located only within soil contamination areas if the contamination is not removable. Five to seven soil contamination areas should be selected. Seven stations should be selected for each selected fixed soil contamination area. These stations should transect the contamination area with one station at or near the highest radiation levels in the areas, two stations where the radiation levels are approximately 50 percent of the highest levels, two stations near the edge of the posted area, and two stations a short distance outside of the posted area.

  Identification of soil contamination areas with fixed contamination is currently in process (Demarcation Study). As the results of this study become available, environmental TLD stations that meet the criteria stated above will be selected. In the interim, TLDs that are posted at contamination area boundaries (i.e., at the edge of roads through contaminated areas, etc.) will continue to be posted. There are 43 TLDs in this category, as listed in Table 4.10. All or most of these stations will be deleted after posting of TLDs at environmental TLD stations meeting the above criteria has begun.

– ***Waste Management Site Stations:*** DOE Order 5820.2A, "Radioactive Waste Management"; and DOE/LLW-13Tg, Low-Level Waste Management Handbook Series – "Environmental Monitoring for Low-Level Waste Disposal Sites," provide requirements and guidance for monitoring direct radiation around the perimeter of waste management sites. DOE/LLW-13Tg recommends six perimeter stations, with the stations being nearest to where people are located, and near roads and parking areas used by trucks that deliver waste.

  TLDs currently posted around RWMS-5 that meet the above criteria will continue to be posted, and are listed in Table 4.10. These locations may change, with the approval of the Environmental Monitoring Project Manager, if changes in operational activities justify the changes. Four TLDs have been posted around RWMS-3. An additional TLD will be stationed near the office buildings to monitor the radiation levels from the trucks entering the site.

– ***Background Stations:*** Background stations should be selected in areas where the ambient radiation levels are consistent with the radiation levels from natural background at environmental and waste management site stations. Natural background radiation levels vary significantly on the NTS because of elevation variations and geologic features; therefore, background radiation levels should be separated into at least four ranges (e.g., < 6 µR/hr [< 52 mR/yr], 6 to 12 µR/hr [52 to 105 mR/yr], 12 to 18 µR/hr [106 to 158 mR/yr], 18 to 24 µR/hr [159 to 210 mR/yr]); and at least three background stations should be selected for each range. A map of the NTS showing terrestrial exposure rates should be used for preliminary site selection. Final site selection should be made using ground radiation surveys with a PIC or other suitable instrument in accordance with DOE/EH-0173T.

DOE/EH-0173T states "Background or control measurement stations *should* be a minimum distance of 15 to 20 km from the larger sites and 10 to 15 km from the smaller sites in the least prevalent wind direction." For the purpose of selecting control TLD stations, each contaminated soil area, as identified by the flyover data, and each RWMS will be considered a site. Therefore, background TLD stations can be on the NTS while meeting the distance criteria above. Until site-selection work is complete for background stations meeting the criteria above, existing stations that are over 5 km (3 mi) from the nearest source of man-made radiation will be used as control stations, and are listed in Table 4.10.

– ***Historical Stations:*** TLDs have been posted for over ten years at nine stations in areas not affected by soil contamination or other man-made radiation. The radiation levels at these locations are believed not to have changed with time. The reported radiation levels for these locations have varied in unison with time, indicating that the reported radiation level changes are a reflection of changes in the TLD system used and TLD system calibration, rather than in the actual radiation levels. Historical stations are listed in Table 4.10.

PIC Station Site-Selection Criteria

At least one PIC, and preferably two or three, should be posted continuously at one of the background TLD stations. The PIC should be at or near the same height as the TLD. Because the PIC will require frequent servicing (typically weekly), the TLD station(s) selected should be readily accessible.

4.5.4.2 SELECTION OF OFFSITE TLD AND PIC STATIONS

Pressurized ion chambers were first used offsite NTS in 1981 when the Community Radiation Monitoring Program began. At its peak, the PIC network contained 19 stations.

The offsite environmental TLD locations during 1996 included 22 members of the public and 39 locations. It is proposed to eliminate the personnel TLD network and to reduce the environmental TLD locations to six. The locations recommended for TLDs are the same as the six locations proposed for the offsite air particulate samplers. It is recommended that the PIC network be eliminated as other methods for detecting releases due to NTS activities are available.

4.5.4.3 SELECTION OF OTHER FACILITY TLD STATIONS

Monitoring stations at the BN-managed facilities off the NTS will be posted at a height of 1 ± 0.3 m (28 to 51 in) on DOE/NV property which is closest to the nearest point accessible to the public in the predominant direction of the source's output (in the case of a beam-type generating device), or in all directions of the source's output (in the case of sealed sources or an isotropic radiation-generating device). Forty-six facility area monitoring (FAM) TLDs have been selected for the following locations based on these design criteria. TLD station identification numbers for all stations are listed below.

STL, Santa Barbara (Figure 4.7)

Directly in front of and behind (for 180-degree backscatter) the beam in the Febetron (ST141, ST215, ST216).
On fence east of the Californium shed (ST209, ST210).
On fence north of the storage shed (ST199, ST200).

STL, Goleta (Figure 4.8)

Four walls, floor, and ceiling above the sealed tube neutron generators (STNG) in the STNG lab at STL (ST105 to ST119, ST122 to ST136 [30 total TLDs]).
The Californium well vault (ST137).

WAMO (Figure 4.9)

Three accessible fenced sides of the source cage at WAMO (WA013, WA014, WA015, WA016, WA017, WA018).

NLVF (Figure 4.10)

Fence line to the north of the Source Range (LV100, LV101).

4.5.5 SAMPLING FREQUENCY

In all cases, the TLDs are exchanged for analysis on a quarterly basis on approximately the same schedule for the NTS and near-NTS and other facility networks. The PICs will be serviced on the same biweekly schedule as the HTO-in-air samplers.

4.5.6 SAMPLE ANALYSIS

The TLD analysis is performed using automated TLD readers that are calibrated and maintained by the ES&H Division. Once the network design has been approved and is operating under present guidelines, modifications to the analytical procedure for compliance with the ANSI standard (ANSI, 1996) for environmental dosimeters will be instituted.

4.5.7 ACTIONS DEPENDENT ON RESULTS OF MONITORING

For onsite and offsite monitoring, other than FAM TLDs, any statistically significant change in gamma radiation levels with time will be investigated, documented, and corrective action taken, if necessary. For facility monitoring, if FAM TLDs or TENDs indicate that one or more members of the public may receive a dose in excess of 50 mrem/yr, corrective actions shall be taken. Management shall be notified promptly and follow-up and corrective actions taken, including actions to prevent recurrence.

Table 4.1 Air Particulate Sampling Station Network for 1998

Area/No.		Location	Alt		Nstate	Estate	Latitude		Longitude	
01	917	BJY	4265	E	842587	679190	37	3.7933'	116	3.2017'
02	950	2-1 SUBSTA	4379	E	871556	672782	37	8.5750	116	4.4833
03	964	WELL ER 3-1	4703	E	826499	712747	37	1.1055	115	56.3282
03	918	BUNKER 3-300	4300	E	836967	685407	37	2.8290	116	1.9570
03	823	U3AH/AT N		O	836569	686383	37	3.0833	116	1.6083
03	821	U3AH/AT S		O	835324	686871	37	2.9400	116	1.5750
03	612	U-3bh N	3995	O	836866	688284	37	2.7000	116	1.2980
03	613	U-3bh S	4025	O	835144	688397	37	2.5340	116	1.3230
04	603	BUNKER T-4	4400	E	854070	664356	37	5.7032	116	6.2397
05	700	RWMS NE (#4)	3200	O	767997	709401	36	51.4667	115	57.1067
05	709	RWMS W (#7)	3200	O	767963	707412	36	51.3117	115	57.5167
05	716	RWMS S (#9)	3200	O	766036	707410	36	51.1383	115	57.3440
05	961	RWMSTPBLGN	3210	O	766134	708783	36	51.1625	115	57.2355
05	608	WEF NE (RWMS#1)	3300	O	765772	709329	36	51.1200	115	57.0900
05	607	WEF SW	3000	O	765611	708975	36	51.0600	115	57.1900
05	847	DOD	3548	E	772070	709866	36	52.1367	115	57.0033
06	712	YUCCA		E	797908	683207	36	56.4267	116	2.4367
07	705	UE7NS		E	855887	694998	37	5.9683	115	59.9333
09	897	AREA 9-300		E	864602	682310	37	7.4183	116	2.5317
10	893	SEDAN CRATER	4410	E	886679	681275	37	11.0595	116	2.7152
15	706	EPA FARM		E	895614	681865	37	12.5300	116	2.5817
18	610	LITTLE FELLER II N	A			37	7.7130		116	17.6730
20	969	CABRIOLET	5800	E	922616	544590	37	17.0730	116	30.8570
20	601	SCHOONER	5660	E	944477	528552	37	20.6800	116	34.1600
25	889	E-MAD NO	3772	B	748974	606467	36	48.0350	116	18.5517
30	611	BUGGY N		A						

NELLIS AIR FORCE RANGE SAMPLERS

Area/No.		Location	Alt		Nstate	Estate	Latitude		Longitude	
13	604	PROJECT 57	4206	O	941228	721597	37	20.0000	115	54.3200
52	968	CLEAN SLT II	5552	O	109682	515140	37	45.7850	116	36.9110
52	967	CLEAN SLT III	5494	O	1099145	489035	37	46.1700	116	42.3300
52	966	DBLE TRACKS	5042	O	1076971	407161	37	42.4900	116	59.3100

NOTE: E = Environmental sampler, O = Operational sampler, B = Background sampler, and A = Assessment sampler.

Table 4.4 Surface Water Sampling Sites

Location Name	Objective[1]	Location Type	General Location	Coordinates[2] Lat	Long	Analysis	New Loc	Sampling Frequency
Big Springs	2	Surface/spring	Ash Meadows	362230	1161625	Ie	no	3 years
Colson's Pond	2	Surface/spring	Oasis Valley	370438	1164132	Ie	yes	Semiannual
Crystal Pool	2	Surface/spring	Ash Meadows	362513	1161923	Ie	no	3 years
Fairbanks Spring	2	Surface/spring	Ash Meadows	362926	1162030	Ie	no	3 years
Goss Springs	2	Surface/spring	Oasis Valley	365945	1164251	Ie	no	Annual
Longstreet Spring	2	Surface/spring	Ash Meadows	362803	1161932	Ie	no	3 years
Peacock Ranch	2	Surface/spring	Springdale	370148	1164518	Ie	yes	Annual
Revert Spring	2	Surface/spring	Oasis Valley	365504	1164437	Ie	no	Annual
Spicer Ranch	2	Surface/spring	Beatty	365916	1164209	Ie	yes	Annual
E-Tunnel Pond 1	3	Containment pond	NTS Area 12	371116	1161123	P	no	Quarterly
E-Tunnel Effluent	3	Containment pond	NTS Area 12	371110	1161112	P	no	Quarterly
A12 Sewage Pond	3	Sewage Pond	NTS Area 12	371147	1160829	P	no	Quarterly
A22 Sewage Pond	3	Sewage Pond	NTS Area 22	363844	1160019	P	no	Quarterly
A23 Final EPD	3	Sewage Pond	NTS Area 23	363918	1160040	P	no	Quarterly
Central Sewage Pond	3	Sewage Pond	NTS Area 25	364631	1161741	P	no	Quarterly
DAF Sewage Pond	3	Sewage Pond	NTS Area 6	365345	1160232	P	no	Quarterly
Lanl Sewage Pond	3	Sewage Pond	NTS Area 6	365838	1160159	P	no	Quarterly
Reactor Control Swg Pond	3	Sewage Pond	NTS Area 25	364634	1161743	P	no	Quarterly
RWMS Sewage Pond	3	Sewage Pond	NTS Arrea 5	365051	1155708	P	no	Quarterly
Yucca Sewage Pond	3	Sewage Pond	NTS Area 6	365629	1160227	P	no	Quarterly

[1]Objectives:
2 - Aquifer monitoring
3 - Permit complinance

[2] Coordinates-Degrees/min/sec; NAD 27, as provided by the USGS

Analysis Ie - Tritium (Enriched method)
Analysis P - Permit driven constituents

For new locations the first sampling event shall include full chemistry (Type IV analysis, see Table 4-8), including gross alpha and beta, Sr, Pu, and gamma spectroscopy in additon to enriched tritium analysis.

Table 4.5 Offsite USGS Water Level Monitoring Wells for FY 1997

	Station Name
Ash Meadows Network	IMV Bentonite Mine Well
	White Well
	MSH-C Deep Well
	MSH-C Shallow Well
	Amargosa Flat Playa Well
	Fairbanks Swamp Well
	F-Meadows Well
	Rogers Spring ET2 Well
	Rogers Spring Well
	Rogers Spring ET1 Well
	Rogers Spring ET1-D Well
	Trenary Well
	Five Springs Well
	Mine Shaft
	Amargosa Flat Corral Well
	Cold Spring Well
	Buck Mining Hand Dug Well
	Carson West Well
	Peterson Well
	Peterson Reservoir Well
	Garners Well
	Mercury Farms Well
	Spring Meadows Rd Well
	Carson Slough Terrace Well
	Carson Slough 3
	Devils Hole Well
	Spring Meadows 12
	Spring Meadows 11
	SW Drainage North
	Carson Meadows Well
	SW Drainage South
	Spring Meadows 9
	Point of Rocks North Well
	Lower Crystal Well
	Point of Rocks South Well
	Big Spring Well
	B-Spring North Well
	B-Spring South Well
	Carson Slough South Well
	American Resources Well
	GS-1 Well
NTS Offsite Regional Network	UC-1-P-2SR
	HTH-2
	HTH-1
	TTR Reeds Ranch Well
	TTR Sandia 3

Table 4.5 (continued)

	Station Name
NTS Offsite Regional Network (cont.)	TTR EH-7 WW
	TTR EH-6
	TTR 3BB
	TTR 3B WW
	TTR 3A WW
	TTR Sandia 4
	TTR Sandia 2
	TTR EH-2 WW
	TTR EH-4
	TTR Antelope Mine 3
	TTR Antelope Mine 1
	TTR Antelope Mine 2
	TTR Sulfide Mine
	Ralston Well
	TPJ-1
	TPJ-2
	DDL-1
	DDL-2
	TW- 3
	ASH-B Deep Well
	ASH-B Shallow Well
	USAF MW-21
	USAF MW-20
	USAF MW-22
	USAF Well 3
	USAF Well 106-2
	Army 6A
	Cactus Springs 3
	DR-1
	LWS-A Deep Well
	LWS-A Shallow Well
	Army 2
	Army 3
	USAF Well 2372-1
Oasis Valley Network	Springdale Windmill Well
	Springdale Upper Well
	Springdale ET Deep Well
	Springdale ET Shallow Wel
	Springdale Lower Well
	MOV ET Well
	Boiling Pot Road Well
	Pioneer Road Seep Well
	Lower Indian Springs Well
	H.B. Layne Well
	Matheny Well
	Crowell Well

Table 4.6 Groundwater Radiological Monitoring Wells and Sampling Design

Well Name	Objective[1]	Well Type	General Location	Coordinates[2]		Analysis[3]	Sample[3] Frequency	Comments
ONSITE WELLS								
UE-1q	2	Monitoring Well (UGTA recompletion well)	Central Yucca Flat	N841500	E677500	Ie	Annual	TCU & LCA
						II, III, & IV	Biennially	Along TOPGALLANT fault
WW-2	2	Monitoring Well (Decommissioned water well)	N Yucca Flat	N880,000	**E668224**	Ie	Biannually	
						II, III & IV	Biennially	
UE-2ce WW	**2**	**Nonpotable Water Supply Well within an UGTA CAU**	**W Central Yucca Flat**	**N871,100**	**E654,900**	**Ie**	**Biannually**	
						II, III, & IV	**Biennially**	
ER-3-2	2	UGTA Characterization	S Central Yucca Flat	N833,112	E684,015	Ie	Annual	Near Well A;
						II, III, & IV	Biennially	three comp. strings
UE-3e #4	2	Monitoring Well	S Central Yucca Flat	N844,888	E680,001	Ie	Annual	HRMP hole near ALEMAN
						II, III, & IV	Biennially	(U-3kz); 3 comp. strings
U-3cn #5	2	Monitoring Well (UGTA recompletion well)	S Central Yucca Flat	N841255	E687,998	Ie	Annual	BILBY Hydro test hole
						II, III, & IV	Biennially	Pz completion
U-3cn PS#2	*2*	*Source Characterization Well (UGTA recompletion well)*	*S Central Yucca Flat*	*N841,600*	*E688,169*	*I, II, III, & IV*	*3 years*	*BILBY postshot hole*
WW A	2	Monitoring Well (plume monitoring well)	Central Yucca Flat	N833,000	E684,000	Ie	Annual	Inactive water supply well
						II, III, & IV	Biennially	
TW-D	2	Monitoring Well	W Central Yucca Flat	N846,600	E672,600	Ie	Annual	
						II, III, & IV	Biennially	
U-4u PS#2A	*2*	*Source Characterization Well*	*Central Yucca Flat*	*N851,215*	*E680,078*	*I, II, III, & IV*	*3 years*	*DALHART test*

Table 4.6 (continued)

Well Name	Objective[1]	Well Type	General Location	Coordinates[2]		Analysis[3]	Sample[3] Frequency	Comments
ONSITE WELLS (cont.)								
UE-4t	2	Monitoring Well	Central Yucca Flat	N855,565	E680,350	Ie	Annual	Two comp. strings
						II, III, & IV	Biennially	
U-4t PS3A	*2*	*Source Characterization Well*	*Central Yucca Flat*	*N856,640*	*E680,539*	*I, II, III, & IV*	*3 years*	*GASCON test (completed 5/93)*
WW 5B	**1 & 2**	**Potable Water Supply Well**	**Frenchman**	**N747,359**	**E704,263**	**Ie, II & V**	**Quarterly**	
		at S edge of UGTA CAU	**S edge of CAU**			**III, & IV**	**Annual**	
WW 5C	**1 & 2**	**Potable Water Supply Well**	**Frenchman**	**N742,860**	**E705,888**	**Ie, II & V**	**Quarterly**	
		S of the UGTA CAU	**Flat**			**III, & IV**	**Annual**	
UE-5c WW	**2**	**Nonpotable Water Supply**	**Frenchman Flat**	**N760,133**	**E700,997**	**Ie**	**Biannually**	
		west edge of CAU	**Flat**			**II, III, & IV**	**Biennially**	
UE-5n	2	Monitoring Well (plume monitoring well)	Frenchman Flat	N754,460	E706,415	I, II, III, & IV	Biennially	CAMBRIC related 10 pCi/L ^{3}H noted
RNM #1	*2*	*Source Characterization Well*	*Frenchman Flat*	*N755,823*	*E704,831*	*I, II, III, & IV*	*3 years*	*CAMBRIC related (21 degree postshot hole)*
RNM #2S	2	Monitoring Well (plume monitoring well)	Frenchman Flat	N755,200	E704,809	I, II, III, & IV	Biennially	CAMBRIC related (pumping well)
~~UE5 PW-1~~	~~2 & 3~~	~~Area 5 RWMS - RCRA~~	Frenchman Flat	N765,702	E706,832	Ie	Annual	Area 5 RWMS related
						II, III, & IV	Biennially	
~~UE5 PW-2~~	~~2 & 3~~	~~Area 5 RWMS - RCRA~~	Frenchman Flat	N770,396	E709,894	Ie	Annual	Area 5 RWMS related
						II, III, & IV	Biennially	
~~UE5 PW-3~~	~~2 & 3~~	~~Area 5 RWMS - RCRA~~	Frenchman Flat	N771,291	E703,460	Ie	Annual	Area 5 RWMS related
						II, III, & IV	Biennially	
ER-6-1	2	UGTA Characterization	SE Yucca Flat	N814,004	E696,800	Ie	Annual	Comp planned for, but not scheduled.
						II, III, & IV	Biennially	
UE-6e	2	Monitoring Well	S Yucca Flat	N814,000	E688,200	Ie	Annual	Completed in Tpt WTA
		(UGTA recompletion well)				II, III, & IV	Biennially	

Table 4.6 (continued)

Well Name	Objective[1]	Well Type	General Location	Coordinates[2]		Analysis[3]	Sample[3] Frequency	Comments
ONSITE WELLS (cont.)								
WW C	**1 & 2**	**Potable Water Supply Well**	**S Yucca Flat**	**N790,082**	**E692,061**	**Ie, II & V**	**Quarterly**	**LCA completion**
		outside an UGTA CAU				**III, & IV**	**Annual**	**Sample one, C or C-1**
WW C1	**1 & 2**	**Potable Water Supply Well**	**S Yucca Flat**	**N790,011**	**E692,132**	**Ie, II & V**	**Quarterly**	**LCA completion**
		outside an UGTA CAU	**(next to WW C)**			**III, & IV**	**Annual**	**Sample one, C or C-1**
WW 4	**1 & 2**	**Potable Water Supply Well**	**CP Basin**	**N784,999**	**E687,900**	**Ie, II & V**	**Quarterly**	**WTA completion**
		outside an UGTA CAU				**III, & IV**	**Annual**	**Sample one, 4 or 4A**
WW 4A	**1 & 2**	**Potable Water Supply Well**	**CP Basin**	**N784,350**	**E686,900**	**Ie, II & V**	**Quarterly**	**WTA completion**
		outside an UGTA CAU				**III, & IV**	**Annual**	**Sample one, 4 or 4A**
UE-7nS	2	Monitoring Well (plume monitoring well)	E Yucca Flat	N855,600	E693,700	Ie	Annual	BOURBON test related
						II, III, & IV	Biennially	Pz completion; 3H noted
UE-11a	2	Monitoring Well	N Frenchman Flat	N777,130	E708,280	Ie	Annual	Recompleted 1982
						II, III, & IV	Biennially	poss bridge @ SWL
~~ER-12-1~~	~~2 & 3~~	~~UGTA Characterization~~	S. Rainier Mesa	N886,642	E640,539	Ie	Annual	Downgrad from E-tunnel
						II, III, & IV	Biennially	Crossed thrust faults
UE-16d	**1 & 2**	**Potable Water Supply Well**	**W Yucca Flat**	**N844,878**	**E646,567**	**Ie, II & V**	**Quarterly**	
		outside an UGTA CAU				**III, & IV**	**Annual**	
HTH#1	2	Monitoring Well	W of Yucca Flat/	N876,855	E629,310	Ie	Annual	low water yield
			S of Rainier Mesa			II, III, & IV	Biennially	140 pCi/L of ^{3}H noted
WW 8	**1 & 2**	**Potable Water Supply Well outside UGTA CAU**	**S Pahute Mesa**	**N879,468**	**E609,999**	**Ie, II & V**	**Quarterly**	
						III, & IV	**Annual**	
UE-18r	2	Monitoring Well	Timber Mt. Moat	N868,100	E564,700	Ie	Annual	Bridge plug at 763m
						II, III, & IV	Biennially	(2,504 ft)

Table 4.6 (continued)

Well Name	Objective[1]	Well Type	General Location	Coordinates[2]		Analysis[3]	Sample[3] Frequency	Comments
ONSITE WELLS (cont.)								
ER-19-1	2	UGTA Characterization	W Rainier Mesa	N884,237	E624,548	Ie	Annual	Crossed thrust fault to Mc;
						II, III, & IV	Biennially	3 completion intervals
UE-19c WW	**1 & 2**	**Nonpotable Water Supply**	**Pahute Mesa**	**N917,000**	**E601,027**	**Ie & II**	**Biannually**	**inactive**
		Well within an UGTA CAU				**III, & IV**	**Biennially**	
U-19v PS#1	*2*	*Source Characterization Well*	*Pahute Mesa*	*N909,396*	*E592,425*	*I, II, III, & IV*	*3 years*	*USGS Instruments ALEMENDRO Test*
U-19bh	2	Monitoring Well	Pahute Mesa	N902,900	E585,700	Ie	Annual	96" dia. Emplacement hole
						II, III, & IV	Biennially	
ER-20-1	2	UGTA Characterization	SW Area 20	N900,001	E551,000	Ie	Annual	Comp. plans proposed
						II, III, & IV	Biennially	Requires deepening
ER-20-2#1	2	UGTA Characterization	SW Area 20	N896,556	E577,562	Ie	Annual	Satellite hole
						II, III, & IV	Biennially	
ER-20-5 #1	*2*	*UGTA Characterization-Near-field drilling*	*S Central Area 20*	*N899,134*	*E555,174*	*I, II, III, & IV*	*Annual*	*TYBO near-field completed in Tpt WTA*
ER-20-5 #3	*2*	*UGTA Characterization-Near-Field Drilling*	*S Central Area 20*	*N899,031*	*E555,170*	*I, II, III, & IV*	*Annual*	*TYBO near-field Deeper, Tacp LFA*
ER-20-6 #1	*2*	*UGTA Characterization-Near-Field Drilling*	*S Central Area 20*	*N913,791*	*E571,559*	*I, II, III, & IV*	*Annual*	*BULLION near-field (closest to Bullion)*
ER-20-6 #2	*2*	*UGTA Characterization-Near-Field Drilling*	*S Central Area 20*	*N913,692*	*E571,444*	*I, II, III, & IV*	*Annual*	*BULLION near-field*
ER-20-6 #3	*2*	*UGTA Characterization-Near-Field Drilling*	*S Central Area 20*	*N913,420*	*E571,337*	*I, II, III, & IV*	*Biennially*	*BULLION near-field (FGE pumping well)*
U-20 WW	**2**	**Nonpotable Water Supply**	**Pahute Mesa**	**N910,582**	**E569,090**	**Ie, II**	**Biannually**	
		Well within an UGTA CU				**III, & IV**	**Biennially**	
PM-1	2	Monitoring Well	Pahute Mesa	N921,104	E575,868	Ie	Annual	Deep HSU
						II, III, & IV	Biennially	

Table 4.6 (continued)

Well Name	Objective[1]	Well Type	General Location	Coordinates[2]		Analysis[3]	Sample[3] Frequency	Comments
ONSITE WELLS (cont.)								
UE-20n #1	*2*	*Source Characterization Well*	*Pahute Mesa*	*N906,545*	*E571,239*	*I, II, III, & IV*	*3 years*	*HRMP hole CHESHIRE test*
U-20n PS1DDh	*2*	*Source Characterization Well*	*Pahute Mesa*	*N906,531*	*E570,834*	*I, II, III, & IV*	*3 years*	*Recompleted 5/85 CHESHIRE test*
Army #1 WW	**1 & 2**	**Potable Water Supply Well outside UGTA CAU**	**Mercury Valley**	**N670,902**	**E684,774**	**Ie, II & V**	**Quarterly**	
						III, & IV	**Annual**	
~~SM 23-1~~	~~2 & 3~~	~~Sewage Lagoon Monitoring~~	Near the Mercury	N692,662	E690,904	Ie	Annual	
		~~Well~~	Sewage Lagoon			II, III, & IV	Biennially	
UE25p #1	2	Yucca Mountain Project Well	Yucca Mt	N756,171	E571,485	Ie	3 years	Volcanics and LCA 1805 (5,923 ft TD)
UE25 WT #6	2	Yucca Mountain Project Well	Yucca Mt	N780,576	E564,524	Ie	3 years	Volcanics
J-12 WW	**1 & 2**	**Potable Water Supply Well outside UGTA CAU**	**Jackass Flats**	**N733,508**	**E581,012**	**Ie, II & V**	**Quarterly**	**State Water Rights**
						III, & IV	**Annual**	**Permit**
J-13 WW	**1 & 2**	**Potable Water Supply Well outside UGTA CAU**	**Jackass Flats**	**N749,209**	**E579,651**	**Ie, II & V**	**Quarterly**	**State Water Rights**
						III, & IV	**Annual**	**Permit**
OFFSITE WELLS								
PM-3			Offsite, just west	371412	1163337	Ie	Semiannual	HRMP hole,
			of Area 20			II, III, & IV	Biennially	Two comp. strings
USW H-1	2	Yucca Mountain Project Well	Offsite, just west of Area 25	365158	1162700	Ie	3 years	1,829m (6,000 ft) TD
American Resources Well	2	Monitoring Well	Ash Meadows	362148	1161757	Ie	3 years	New well
Amargosa Valley RV Park	2	Community Well	Amargosa Valley	363830	1162352	Ie	3 years	New well
ASH-B (both piezometers)	2	Monitoring Well	Amargosa Valley	364329	1164029	Ie	3 years	

Table 4.6 (continued)

Well Name	Objective[1]	Well Type	General Location	Coordinates[2]		Analysis[3]	Sample[3] Frequency	Comments
OFFSITE WELLS (cont.)								
Barn Well #2, Pond. Dairy	2	Water Supply	Amargosa Valley	362941	1162658	Ie	3 years	New well
Beatty Water and Sewer	2	Community Well	Beatty	365412	1164518	Ie	Annual	
Cherry Patch Well	2	Domestic Well	Amargosa Valley	362929	1160857	Ie	3 years	New well
Cind-R-Lite Mine	2	Water Supply	Amargosa Valley	364105	1163026	Ie	3 years	
Coffer's Ranch Windmill	2	Water Supply	Oasis Valley	370014	1163325	Ie	Semiannual	
						II, III, & IV	Annual	
Cook's Ranch Well #2	2	Domestic Well	Amargosa Valley	363430	1162351	Ie	3 years	New well
De Lee Ranch	2	Domestic Well	Amargosa Valley	363248	1163031	Ie	3 years	New well
Fire Hall #2 Well	2	Water Supply	Amargosa Valley	362442	1162511	Ie	3 years	New well
Last Trail Ranch	2	Domestic Well	Amargosa Valley	363406	1163606	Ie	3 years	New well
Longstreet Casino Well#1	2	Water Supply	Amargosa Valley	362451	1162533	Ie	3 years	New well
Low-Level Waste Site	2	Water Supply	Beatty	364610	1164130	Ie	Annual	New well
Road D Well, Spicers	2	Water Supply	Beatty	370255	1165034	Ie	Annual	
Roger Bright Ranch	2	Domestic Well	Amargosa Valley	362914	1163043	Ie	Annual	New well
School Well	2	Community Well	Amargosa Valley	363411	1162740	Ie	Annual	New well
TW-5	2	Monitoring Well	Amargosa Valley	363815	1161759	Ie	Annual	
Tolicha Peak	2	Water Supply	Tolicha Peak	371732	1164725	Ie	Annual	
Younghan's Ranch	2	Domestic Well	W. Oasis Valley	370141	1164309	Ie	Annual	
ER-OV-01	2	UGTA Monitoring Well	N. Oasis Valley	370504	1164049	Ie	Semiannual	New well
						II, III, & IV	Annual	
ER-OV-02	2	UGTA Monitoring Well	C. Oasis Valley	370210	1164215	Ie	Semiannual	New well
						II, III, & IV	Annual	
ER-OV-03a	2	UGTA Monitoring Well	C. Oasis Valley	365956	1164216	Ie	Annual	New well

Table 4.6 (continued)

Well Name	Objective[1]	Well Type	General Location	Coordinates[2]		Analysis[3]	Sample[3] Frequency	Comments
OFFSITE WELLS (cont.)								
ER-OV-03a3	2	UGTA Monitoring Well	C. Oasis Valley	365956	1164216	Ie	Annual	New well
ER-OV-03c	2	UGTA Monitoring Well	E. Oasis Valley	365948	1163604	Ie	Semiannual	New well
						II, III, & IV	Annual	
ER-OV-03c2	2	UGTA Monitoring Well	E. Oasis Valley	365948	1163604	Ie	Semiannual	New well
						II, III, & IV	Annual	
ER-OV-04a	2	UGTA Monitoring Well	S. Oasis Valley	365705	1164242	Ie	Annual	New well
ER-OV-05	2	UGTA Monitoring Well	N.W. Springdale	370246	1164619	Ie	Annual	New well
ER-OV-06a	2	UGTA Monitoring Well	N. Oasis Valley	370504	1164049	Ie	Semiannual	New well
						II, III, & IV	Annual	

[1]Objectives:
1 - Supply well monitoring
2 - Aquifer monitoring
3 - Permitted facilities monitoring

Abbreviations:
C - Central; W - West; E - East; S - South; SW - Southwest; UGTA - Underground Test Area
WTA - Welded Tuff Aquifer
TCU - Tuff Confining Unit
LCA - Lower Carbonate Aquifer
CAU - Corrective Action Unit

[2]Coordinates: for onsite locations are Central Nevada State Planar, in feet; NAD 27, from the NTS Drilling and Mining Summary (RSN, 1991).
for offsite locations are given in latitude and longitude, degrees/min/sec; NAD 27, as provided by the USGS.

[3]See Section 4

Sampling Frequency may vary based upon well and attendant equipment availability (e.g., pumps).

Underline = Regulatory Mandates | **Bold = Water Supply Wells**

Regular font = Conventional monitoring wells | *Italic =Source term wells*

Table 4.7 Onsite Water Level Monitoring Wells

Well Name	General Location
AREA 1	
UE-1c	W Yucca Flat
UE-1h	SW Yucca Flat
UE-1r	S Central Yucca Flat
UE-1k	S Central Yucca Flat
AREA 3	
U-3cn #1	S Central Yucca Flat
U-3mi	SE Yucca Flat
TW-7	E Yucca Flat
AREA 4	
UE-4av	W Central Yucca Flat
AREA 5	
WW-5a	Frenchman Flat
AREA 6	
UE-6d	S Yucca Flat
TW-B	S Yucca Flat
ER-6-2	SW Yucca Flat

Table 4.7 (continued)

Well Name	General Location
AREA 7	
U-7cd	Central Yucca Flat
AREA 9	
U-9ct	N Yucca Flat
AREA 12	
UE-12t #6	Rainier Mesa
U-12s	Gold Meadows
AREA 15	
UE-15d	N Yucca Flat Climax Stock
AREA 18	
UE-18t	Timber Mt. Moat
AREA 19	
U-19bj	Pahute Mesa
UE-19h	Pahute Mesa
AREA 20	
PM-2	Pahute Mesa
UE-20e #1	Pahute Mesa
UE-20bh #1	Pahute Mesa
AREA 30	
ER-30-1	E. of Timber Mt.

Table 4.8 Sampling and Analysis Design for Groundwater Radiological Monitoring Wells

Well Type		Sample Analysis	Sample Frequency	Regulatory Driver
Onsite locations	Potable water supply well within CAU	Ie, II & V	Quarterly	Title 40 CFR 141, DOE Order 5400, and SDWA
		III+ & IV	Annually	
	Other potable water supply well	Ie, II & V	Quarterly	DOE Order 5400 Series and SDWA
		III+ & IV	Annually	
	CAU nonpotable water supply well	Ie	Semiannually	DOE Order 5400 Series
		II, III, & IV	Biennially	
	Monitoring Well (Non-water supply)	Ie	Annually	DOE Order 5400 Series
		II, III, & IV	Biennially	
	Source Characterization Well[1]	I, II, III, & IV	3 years[2]	DOE Order 5400 Series
	New Wells	Ie, II, III, & IV	Semiannually[3]	DOE Order 5400 Series
	Surface Waters (sewage lagoons and containment ponds)	Permit-driven Constituents	Permit-driven	State Permits
Offsite locations[4]	Group A locations (Oasis Valley and vicinity)	Ie	Semiannually	Title 40 CFR 141 and DOE Order 5400
		II, III & IV	Annually	
	Group B locations (more distant)	Ie	Annually	DOE Order 5400 Series
	Group C locations (most distant)	Ie	3 years	DOE Order 5400 Series
	New locations	Ie, II, III+, IV	First sample[illegible]	Title 40 CFR 141 and DOE Order 5400

Note: All parameters and frequencies of analysis are subject to revision after data are acquired and reviewed, if justified. Some sampling events at water supply wells may be skipped, with program management approval, if the well is not being used. CAUs are as defined by [illegible] GTA Project (FFACO, 1996).

1) Source Characterization Wells are currently known as the Hot Well Network. Additional sampling [illegible] parameters may be specified for each hot well.
2) Three-year frequency can be modified for well-specific sampling program.
3) After four semiannual samples are acquired for initial characterization, sampling parameters and freq[illegible]ency will be based on the well type.
4) Offsite locations include both drilled wells and natural springs.

Type I Analysis includes Standard Tritium; at select wells, enriched tritium analysis (Type Ie) will be perfo[illegible]ed
Type II Analysis includes Gross Alpha and Gross Beta.
Type III Analysis includes Gamma spectroscopy and Plutonium. Type III+ analysis includes Type III plus [illegible]90.
Type IV Analysis includes pH, Specific Conductivity, Temperature, Principle Cations/Anions, Total Dissolve[illegible]d Solids, Alkalinity, and Bicarbonate.
Type V Analysis includes ^{226}Ra and ^{228}Ra.
Miscellaneous studies/analyses may also be conducted as deemed appropriate or useful to the overall progra[illegible] (e.g., studies of colloidal particles and their mineralogy).

Table 4.9 Sampling and Analysis Schedule for NTS Drinking Water System Consumption Endpoints

Endpoint	System	Supply Wells	Sampling Frequency	Analysis
Area 6, Cafeteria	No. 1	Wells C-1, 4, and 4A	Quarterly	Ie, II, III
Area 6, Building 6-400			Quarterly	Ie, II, III
Area 2, Restroom	No. 2	Well 8	Quarterly	Ie, II, III
Area 12, Building 12-23			Annually	Ie, II, III
Area 1, Building 101	No. 3	Well UE-16d	Annually	Ie, II, III
Area 23, Cafeteria	No. 4	Wells 5B and Army No. 1	Quarterly	Ie, II, III
Area 25, Building 4221	No. 5	Wells J-12 and J-13	Annually	Ie, II, III

[1]Analysis

Type Ie: Includes tritium (enriched method).
Type II: Includes gross alpha and gross beta.
Type III: Includes gamma spectroscopy, ^{238}Pu, $^{239+240}Pu$, and ^{90}Sr (annually).

Table 4.10 Onsite TLD Stations

AREA	HPD #	LOCATION	TYPE
01	293	BJY	E
01	428	STAKE C-2	E
01	429	BUNKER 1-300	E
01	381	SANDBAG STORAGE HUT	E
02	296	STAKE M-140	E
02	297	STAKE N-8	E
02	298	STAKE L-9	E
02	321	STAKE TH-58	E
03	275	STAKE OB-20	E
03	280	LANL TRAILERS	E
03	281	STAKE A-6.5	E
03	425	U-3co N	E
03	426	U-3co S	E
03	430	WELL ER 3-1	E
03	413	A3 RWMS N	W
03	414	A3 RWMS E	W
03	415	A3 RWMS S	W
03	416	A3 RWMS W	W
03	444	A3 RWMS CENTER	W
03	274	STAKE OB-11.5	E
04	294	STAKE A-9	E
04	431	STAKE TH-41	E
04	320	STAKE TH-48	E
05	249	WELL 5B	H
05	253	RWMS NE CORNER	W
05	257	RWMS NW CORNER	W
05	261	RWMS SW CORNER	W
05	263	RWMS S GATE	W
05	264	RWMS E GATE	W
05	434	RWMS BUILDING 5-31	W

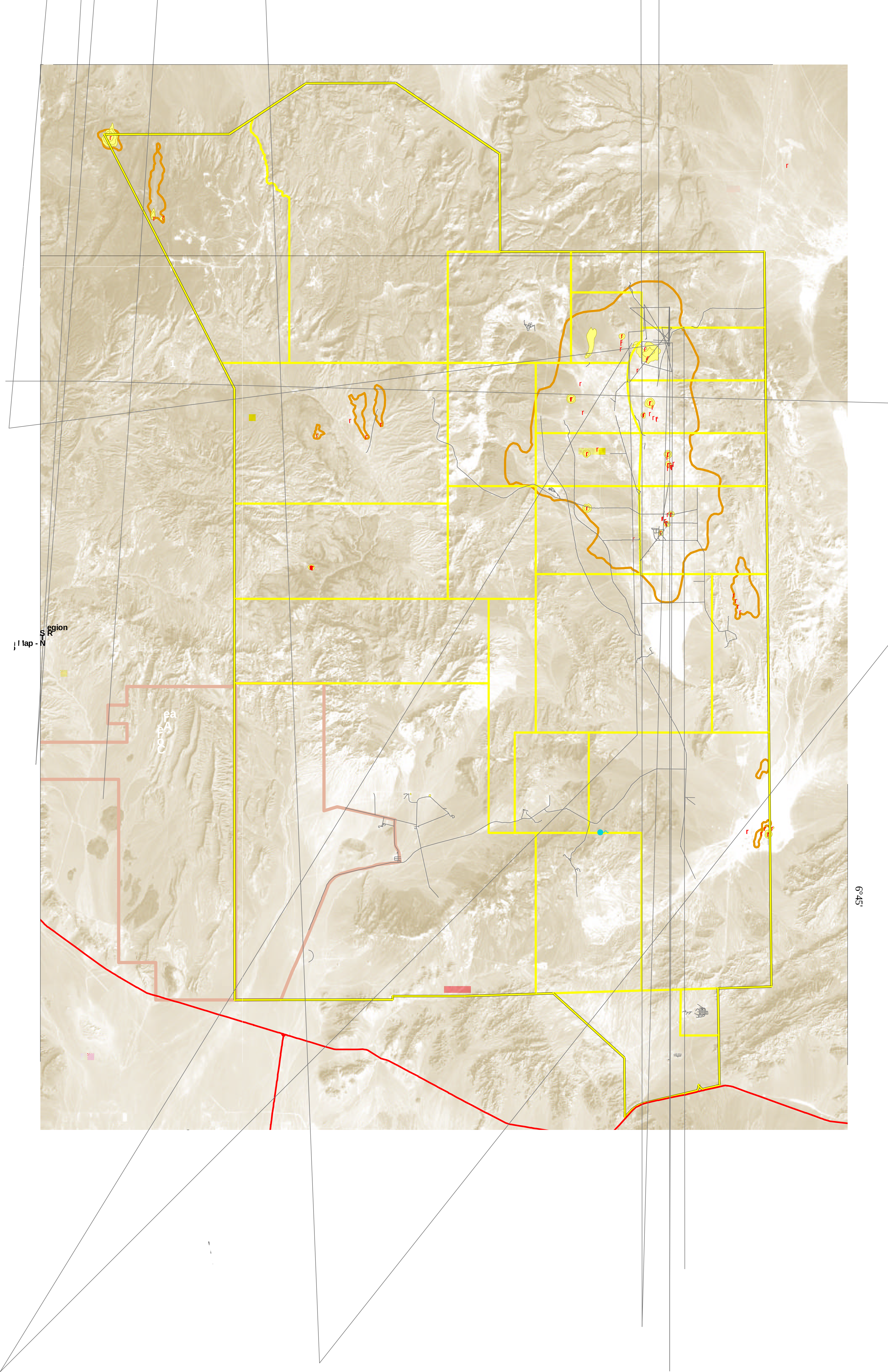
Table 4.10 (continued)

AREA	HPD #	LOCATION	TYPE
05	402	3.3 MI SE OF AGGREG PIT	B
05	421	WEF W	W
05	422	WEF S	W
05	423	WEF E	W
05	424	WEF N	W
06	266	CP-6	H
06	270	YUCCA OIL STORAGE AREA	H
06	407	DAF E	E
06	409	DAF W	E
06	417	DECON PAD NW	E
06	419	DECON PAD SE	E
07	314	7-300 BUNKER	E
07	634	REITMAN SEEP	E
07	435	STAKE H-8	E
08	306	STAKE K-25 (K-24)	E
08	436	ROAD 8-02	E
08	437	STAKE M-152	E
09	313	9-300 BUNKER	E
09	386	PAPOOSE LAKE RD	B
09	635	V&G ROAD JUNCTION	E
09	636	CRATER U-9cw	E
10	302	SEDAN W	E
10	303	SEDAN E VISITOR BOX	E
10	312	CIRCLE & L ROAD	E
10	438	GATE 700 SOUTH	E
11	439	STAKE A-23	E
12	323	T-TUNNEL #2 POND	E
12	325	UPPER N POND	E
12	327	UPPER HAINES LAKE	E

Table 4.10 (continued)

AREA	HPD #	LOCATION	TYPE
12	427	GOLD MEADOWS SPRING	B
15	305	EPA COMPLEX	E
15	310	SUBSTATION U-15e	E
18	385	STAKE A-83	E
18	440	STAKE F-11 (Airport Road)	E
18/30	405	JCT CAT CAN & BUGGY	E
19	335	STAKE P-41	E
19	343	STAKE C-27	B
19	361	STAKE P-77	B
19	366	STAKE R-26	B
19	387	GATE 19-3P, KAWICH	B
20	377	STAKE J-31	E
20	382	STAKE J-41	E
20	383	STAKE LC-4	B
20	384	STAKE A-118	B
22	400	ARMY WELL #1	B
23	231	BUILDING 650 DOSIMETRY	H
23	232	BUILDING 650 ROOF	H
23	233	POST OFFICE	H
25	240	NRDS WAREHOUSE	H
25	241	25-4P GATE	B
25	247	HENRE	H
25	401	JACKASS FLATS & A27 RD	B
25	403	GUARD STATION 510	B
25	404	YUCCA MTN (west of NTS)	B
27	248	AREA 27 CAFETERIA	H

B = Background Stations
E = Environmental Stations
H = Historical Stations
W = Waste Management Site Stations



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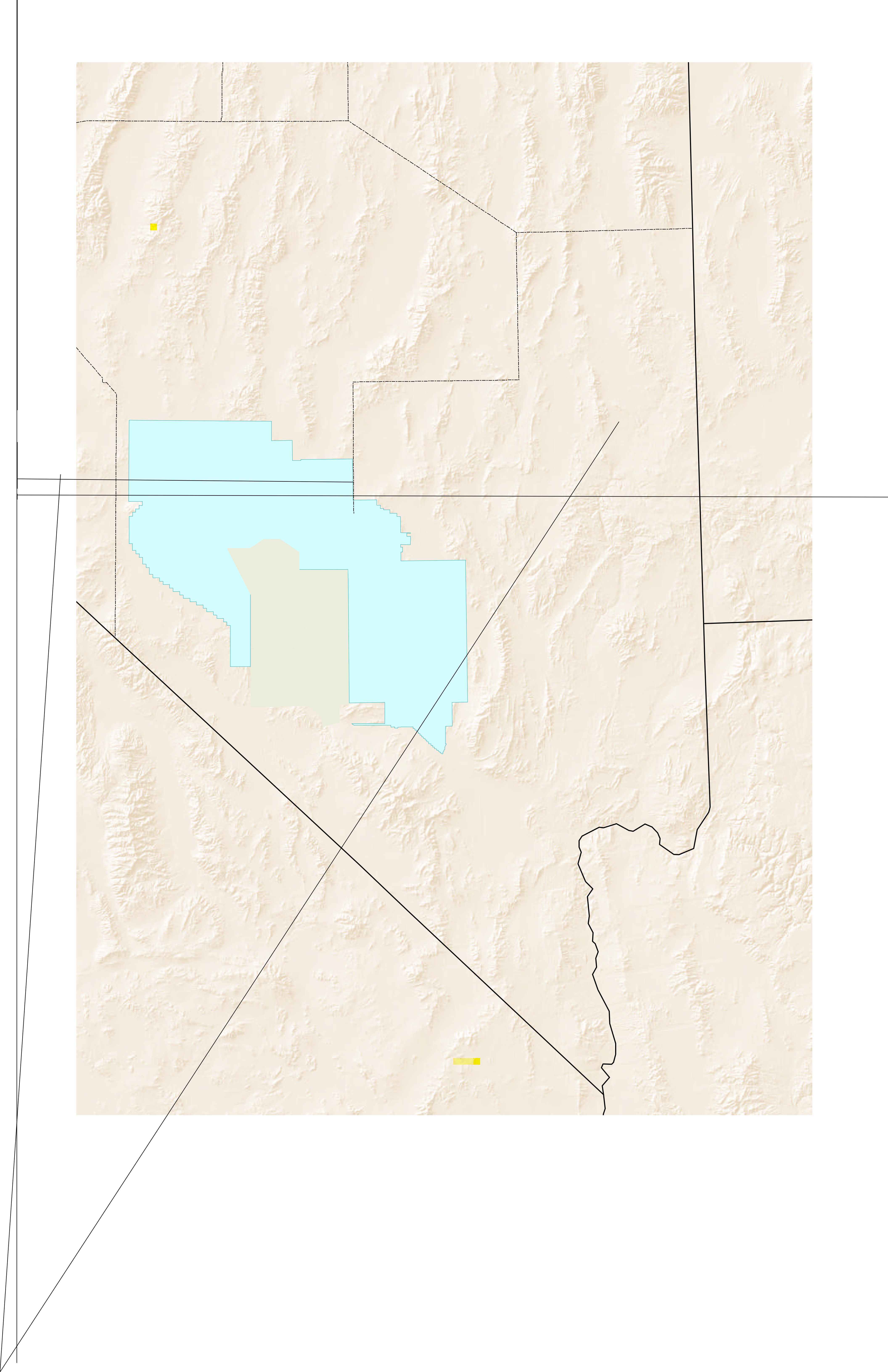

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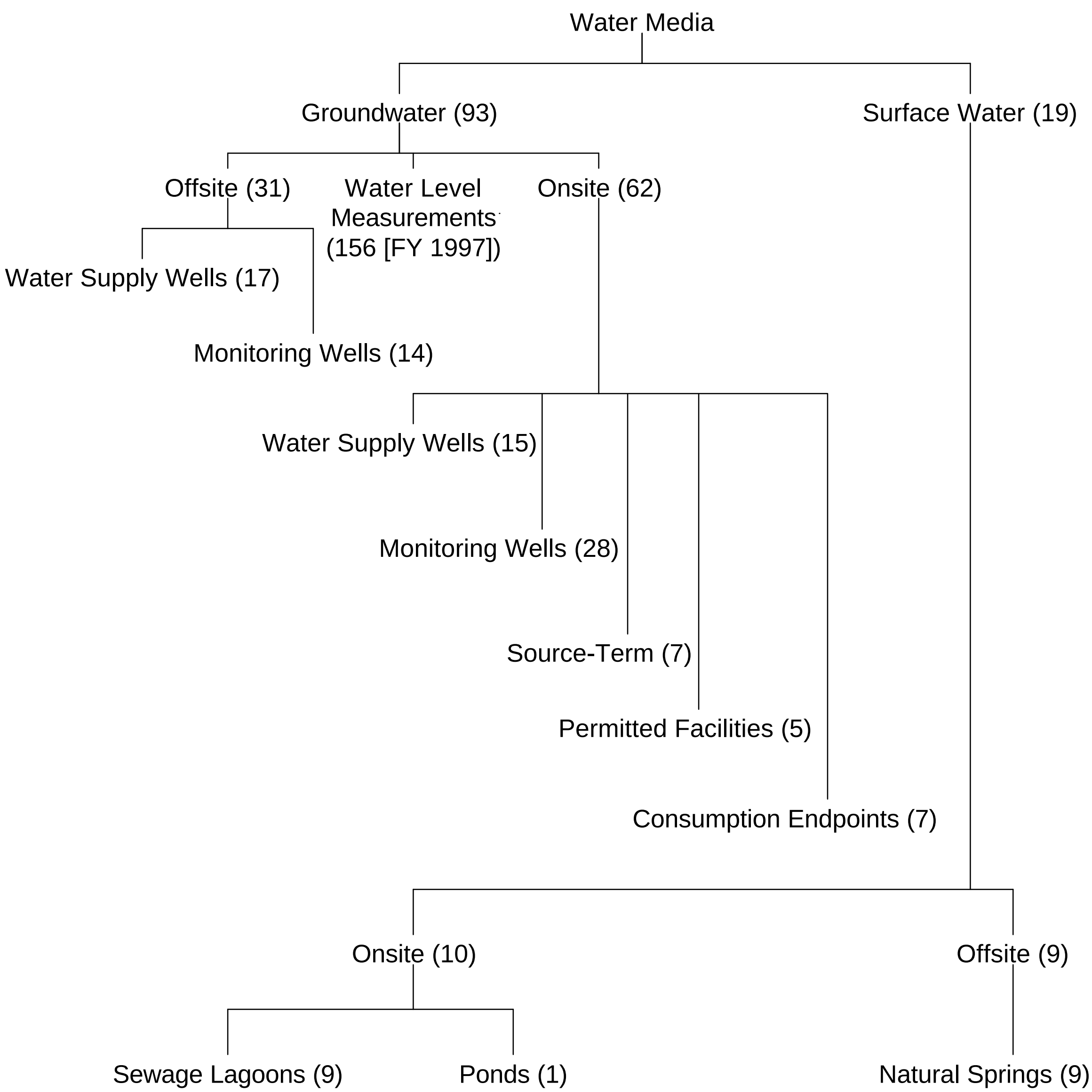

Figure 4.3 Water Monitoring Network Relationship Diagram

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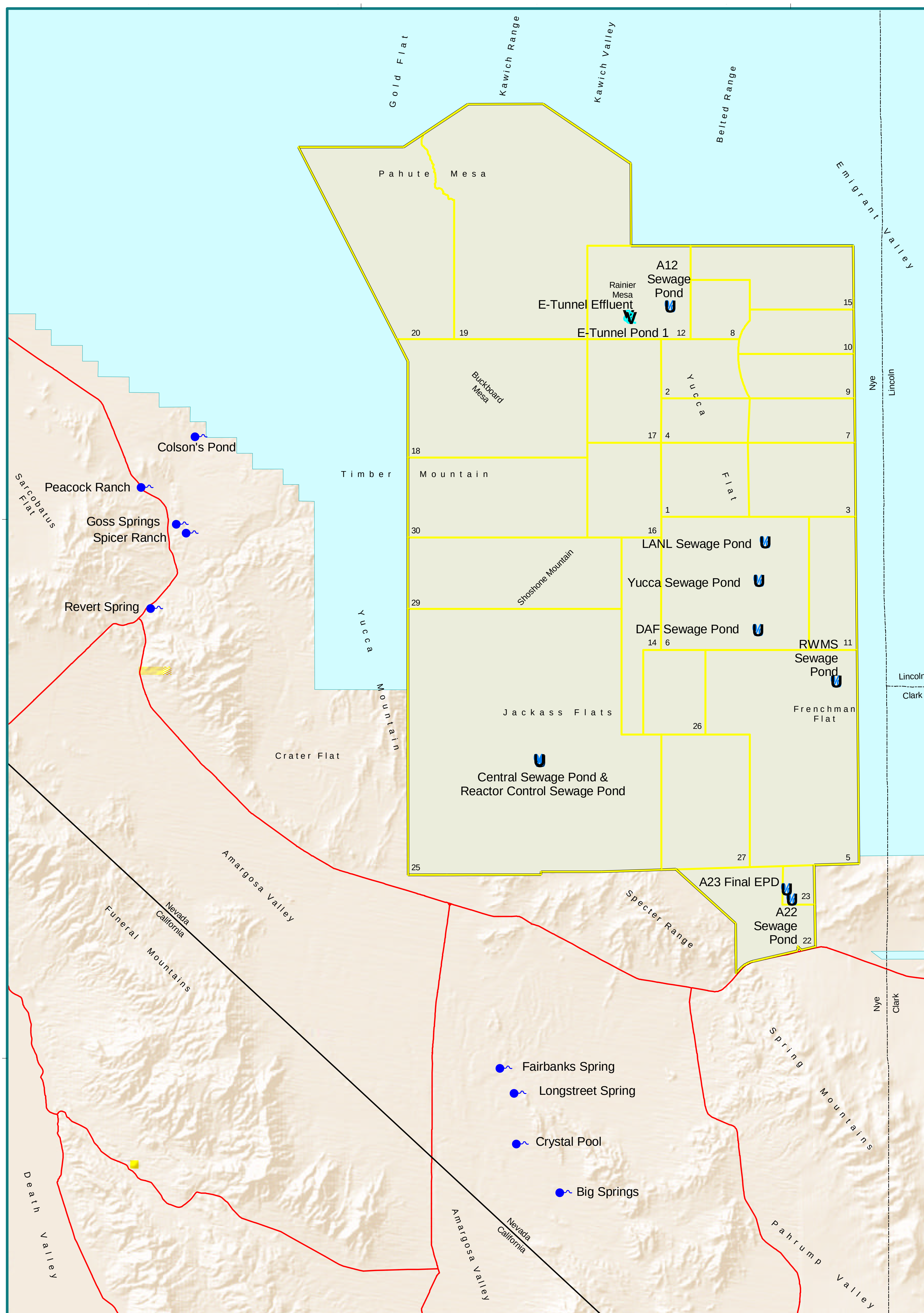


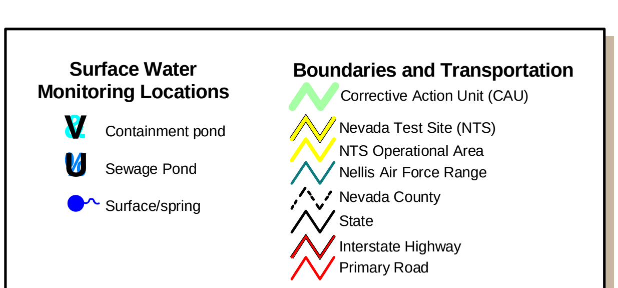
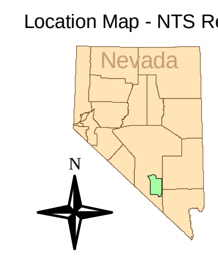


Figure 4.4
NTS Region Surface Water Radiological Monitoring Sites

5 0 5 10 15 20
Kilometers
5 0 5 10
Miles



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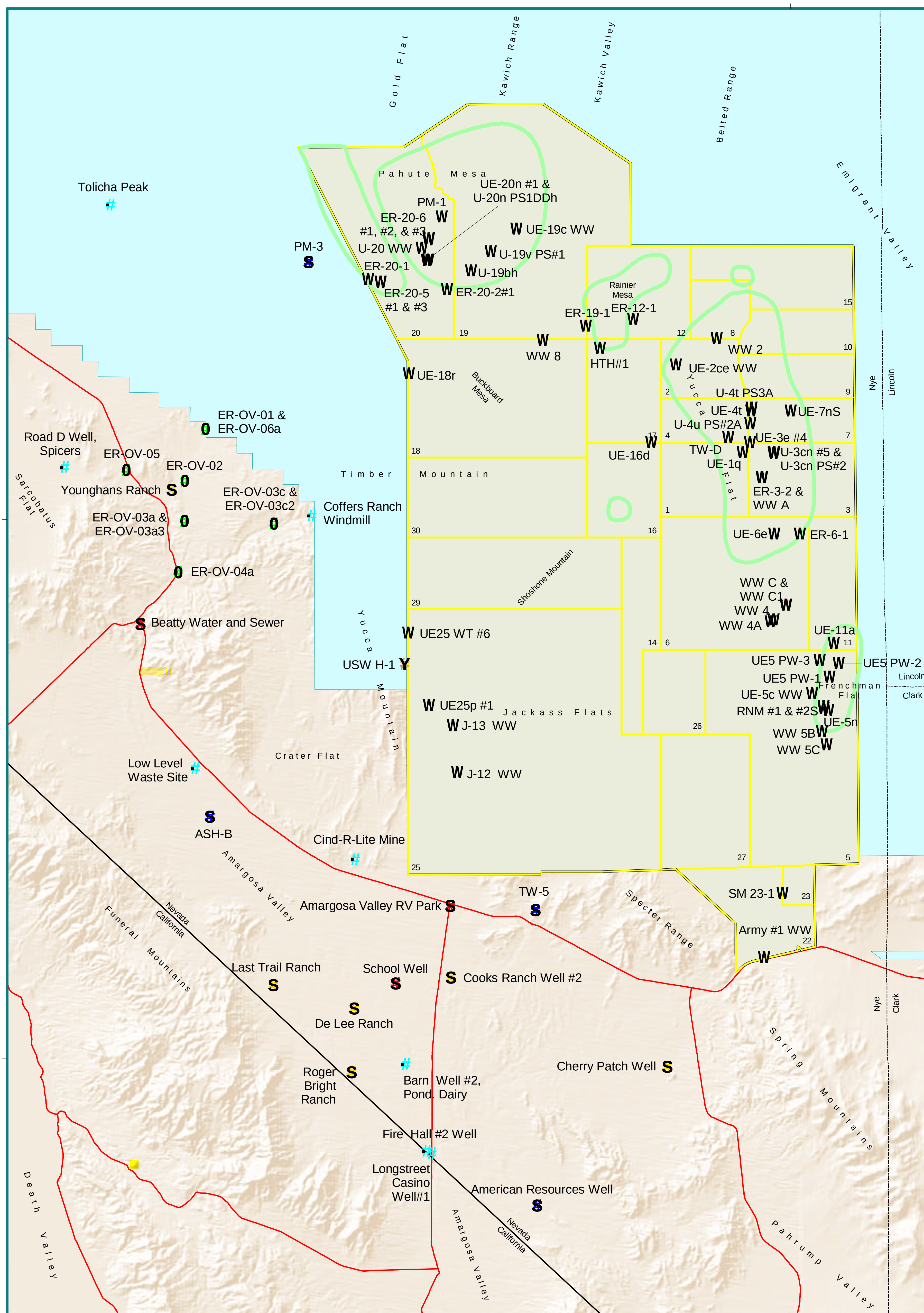

Offsite Monitoring Locations
- UGTA Monitoring Well
- Monitoring Well
- Community Well
- Domestic Well
- Water Supply
- Yucca Mountain Project Well

Onsite Monitoring Locations
- Area 5 RWMS - RCRA
- Monitoring Well
- Nonpotable Water Supply Well
- Potable Water Supply Well
- Sewage Lagoon Monitoring Well
- Source Characterization Well
- UGTA Characterization
- Yucca Mountain Project Well

Boundaries and Transportation
- Corrective Action Unit (CAU)
- Nevada Test Site (NTS)
- NTS Operational Area
- Nellis Air Force Range
- Nevada County
- State
- Interstate Highway
- Primary Road

Figure 4.5
NTS Region Groundwater Radiological Monitoring Sites

Location Map - NTS Region

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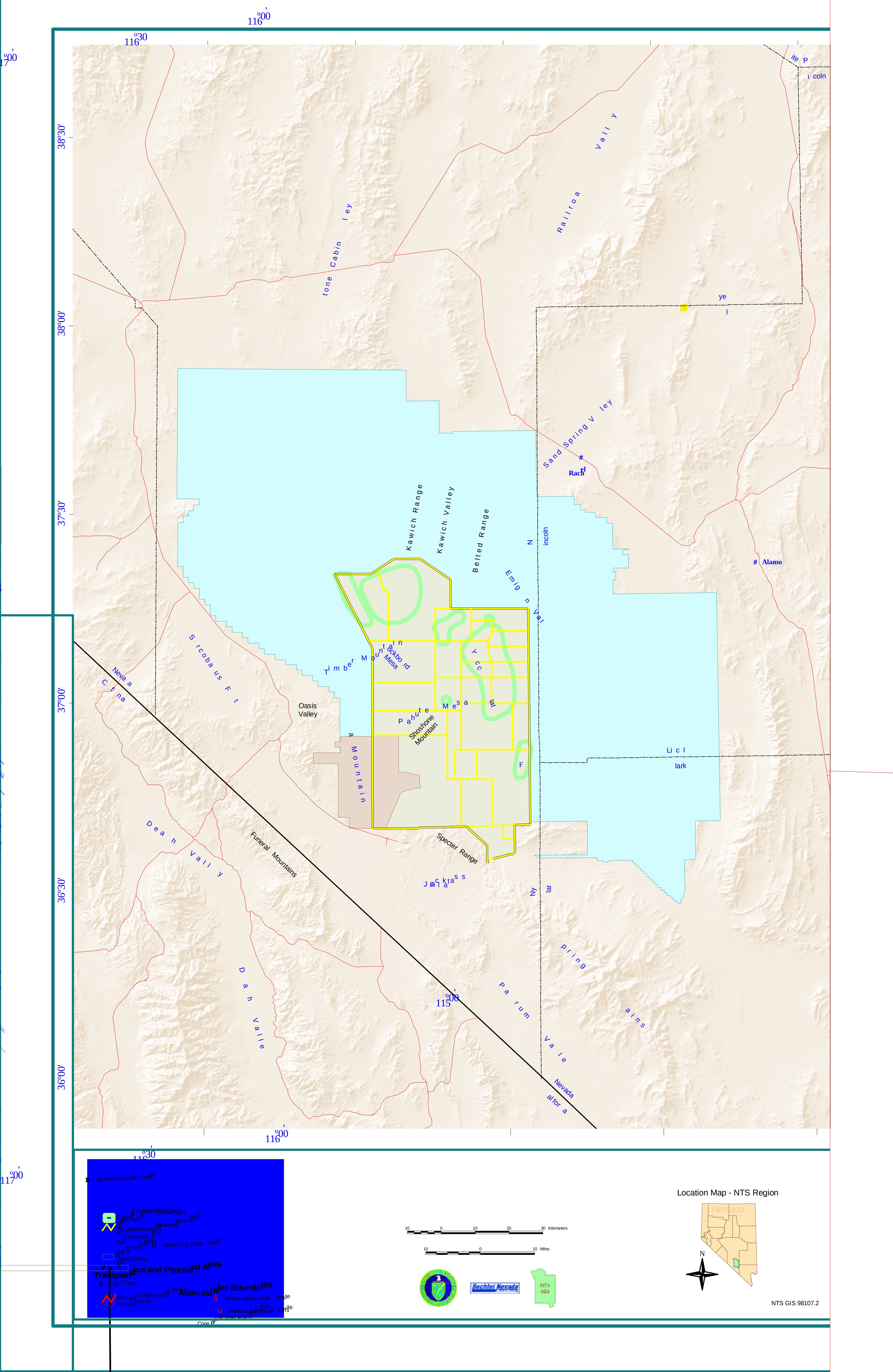

Kawich Range
Kawich Valley
Belted Range
Sand Spring Valley
Rachel
Alamo
Oasis Valley
Shoshone Mountain
Funeral Mountains
Specter Range
Location Map - NTS Region
Nevada
N
Kilometers
Miles
Bechtel Nevada
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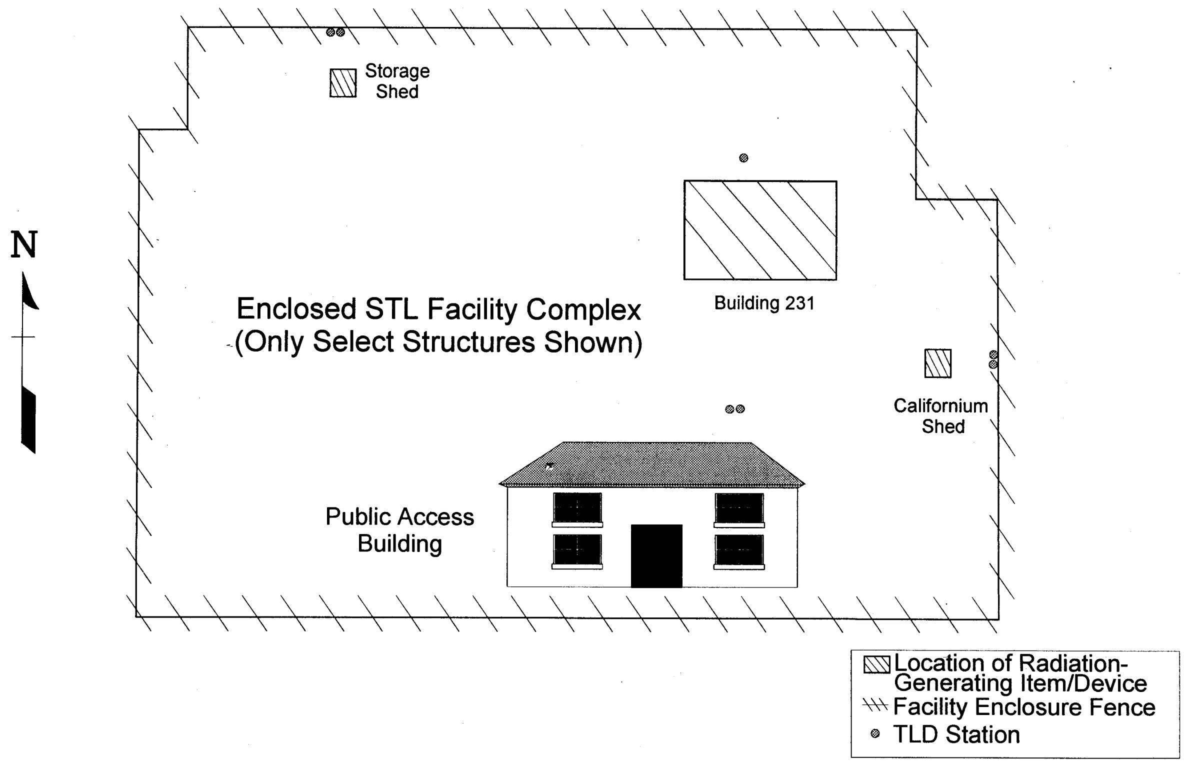

Figure 4.7 Santa Barbara STL Facility TLD Locations

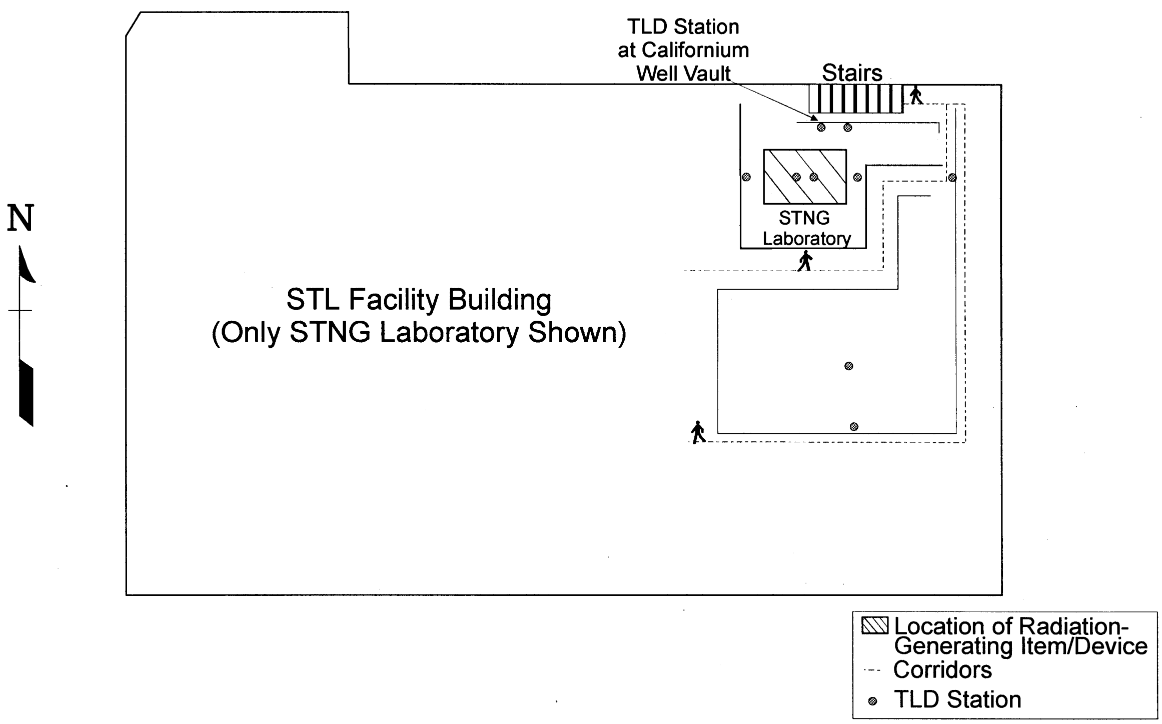

Figure 4.8 Goleta STL Facility TLD Locations

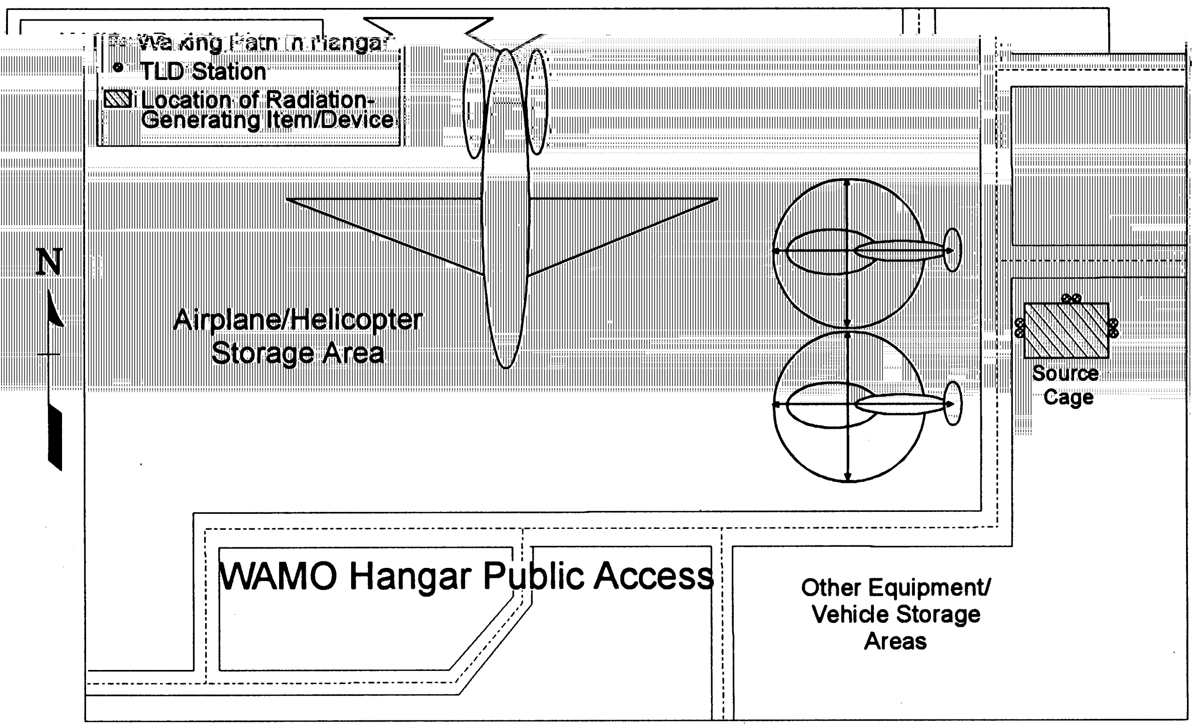

Figure 4.9 WAMO Facility TLD Locations

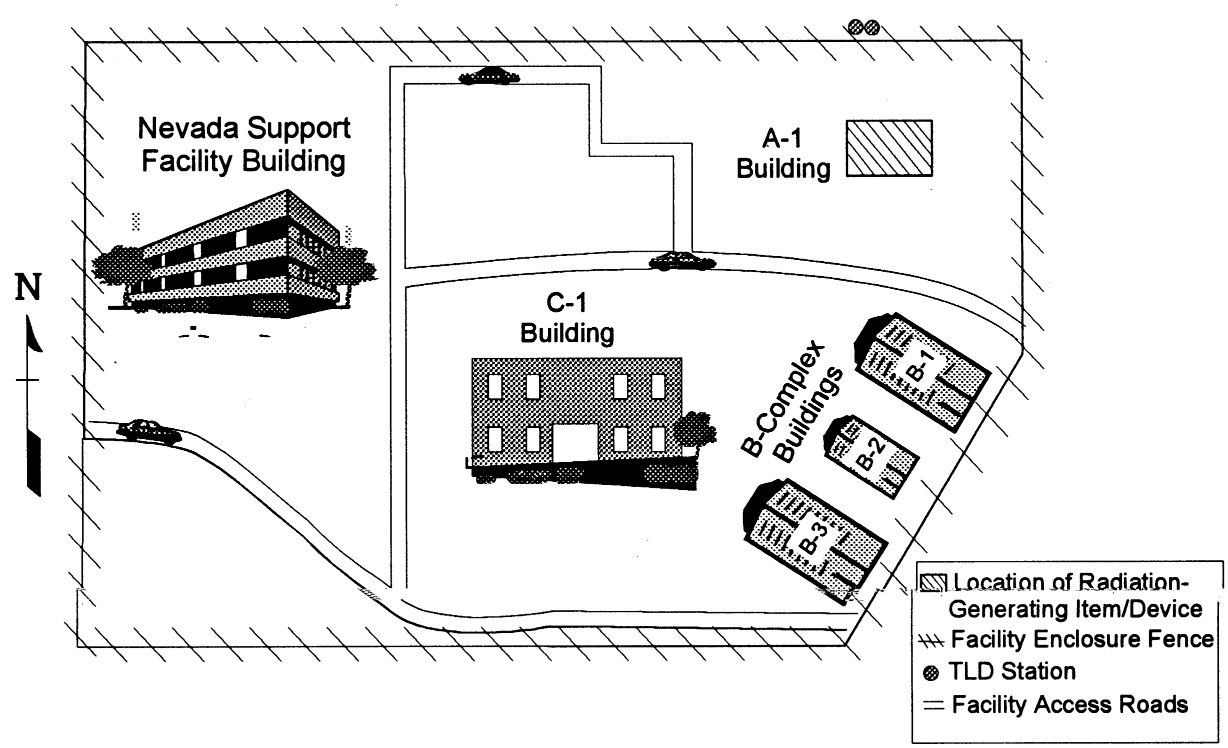

Figure 4.10 NLV Facility TLD Locations

5.0 SUMMARY OF OPERATIONAL MONITORING DESIGN REQUIREMENTS

Operational monitoring is used to assess the total emissions from an operating facility. Operating facilities at the NTS include permanent facilities such as the waste management sites and temporary facilities such as environmental remediation sites.

Several drivers, both DOE Orders and federal regulations, require operational monitoring. DOE/NV Order NV 5400.1, “General Environmental Protection Program,” specifies that an environmental study shall be conducted prior to the startup of a new DOE site, facility, or process that has the potential for significant adverse environmental impact. Under DOE Order 5400.1, a preoperational monitoring study is to begin not less than one year prior to startup when time and circumstance allow. Title 40 CFR 61, Subpart H (NESHAPs), also requires operational monitoring of any facility with the potential to cause an offsite dose of 0.1 mrem/yr. Operational monitoring is also conducted on the NTS to confirm that environmental emissions are “As Low As Reasonably Achievable” under the guidance of proposed Title 10 CFR 834 and 835 (final rule).

Operational monitoring is presently conducted at operational facilities such as RWMSs and the TTR ER Projects. Proposed facilities that could have the potential to cause an offsite dose of 0.1 mrem/annum will be reviewed and monitored as operational facilities. When an operational facility is closed, the facility will again be reviewed for its potential to cause an offsite dose of 0.1 mrem. Any facility that continues to have that potential will be monitored for as long as the potential remains. Although no facility onsite the NTS presently is operated in a manner to have the potential to emit enough radioactivity to cause a 0.1 mrem offsite dose, the entire NTS is treated as a single source for the purposes of NESHAPs, and activities such as remediation of contaminated soils on the NTS and the TTR are considered subject to the requirement for operational monitoring because of the consequence to increase airborne emissions during remedial activities.

Operational monitoring, sometimes considered effluent monitoring, is routinely conducted under the technical guidance of the RREMP. Environmental sampling locations at existing permanent facilities are addressed in Chapter 4 of this document.

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6.0 DATA MANAGEMENT

The RREMP describes the need for environmental data and the details of the collection and analysis of environmental data to support various drivers at the NTS. The technical design of the RREMP is based on use of a decision-based approach to define the environmental data requirements and the data quality which must be achieved. The collection, analysis, and evaluation of data on the environment is the central task of all EM work. A data management system is essential for understanding and sustaining the quality of data collected under the program, allowing programs to identify data gaps or data requirements for other environmental efforts, and eliminating unnecessary duplication of data collection efforts. Because decisions are based on environmental data, and the effectiveness of operations is measured at least in part by environmental data, reliable and accurate records of defensible environmental data are essential. Detailed records that must be kept include temporal, spatial, numerical, geotechnical, chemical, and radiological data, and all sampling and analytical procedures used. Failure to maintain these records in a secure but accessible form may result in exposure to legal challenges and the inability to respond to demands from regulators and third parties.

A data management plan addressing environmental data collected under this RREMP is presently under preparation, and that plan will describe specific data management objectives and standards for the following data issues: format, compatibility, accessibility, archiving, data user interfaces, software/hardware limitations, and documentation of data quality. The plan will describe how data collected under this program will be entered into an information system that can store raw data, data qualifiers, and other comments associated with verification and validation information, and data quality information. The information system will be designed to allow data queries and retrievals for purposes of evaluation, trending and reporting, and archiving data for future use.

An example of how this plan will establish standards for one of the numerous data issues listed above is presented here for the issue of format and quality of geospatial data. This issue is critical to the implementation of monitoring under this plan. Environmental monitoring data collected under this RREMP will include sample location data that will be displayed using Geographic Information System (GIS) formats. The accuracy with which the monitoring locations are described and the precision of the initial field surveying of the locations affect the quality of all evaluation processes of the spatial data and the quality of GIS map products. The data management plan will therefore establish the following meta-data standards for geospatial data:

Projection: Geographic (Longitude, Latitude)
Units: Decimal Degrees, Decimal Minutes
Datum: NAD83
Spheroid: GRS80
Position Accuracy: · 30 meters

The spatial data standards for all groundwater monitoring locations will be those consistent with the DOE/NV ER Division NTS UGTA Project requirements. The data management plan will also specify that each data point will be plotted on a hard copy, 7.5-minute USGS topographic map. The plan will further specify standards for spatial data collection, filing of all hard copy spatial data, entry of spatial data into an electronic geospatial information system, and retrieval of GIS data.

During development of the data management plan, the locations of all monitoring stations from which data are reported, and all pertinent temporal, numerical, geotechnical, chemical, and radiological data gathered under this RREMP will be summarized and published annually in the ASER. The hard copy file will serve as the location of records for all monitoring station data until data are entered into the electronic data information system which will be developed to fully implement the data management plan.

7.0 RELATIONSHIP OF ROUTINE RADIOLOGICAL ENVIRONMENTAL MONITORING PLAN TO OTHER ENVIRONMENTAL MONITORING PROGRAMS AT THE NEVADA TEST SITE

Environmental monitoring at the NTS historically has been and continues to be performed by several programs and federal agencies under the auspices of the DOE/NV. Data collected through environmental monitoring programs includes temporal, spatial, numerical, geotechnical, chemical, radiological, meteorological, and biological data. This RREMP addresses the need to monitor radiological impact of DOE activities at the NTS on the environment and the public, both on- and offsite, based on DOE Order 5400.1 and other technically driven environmental requirements. Related programs are conducted on and in the vicinity of the NTS and, where feasible, data from these programs are integrated with data collected under this RREMP to ensure a thorough understanding of environmental issues at the NTS. Related programs include:

Operational environmental monitoring at the RWMS facilities and other facilities on the NTS.

Compliance monitoring conducted to ensure that NTS facilities permitted by state and federal agencies are in compliance with state and federal regulations.

Site characterization and environmental restoration data acquisition programs conducted on historic contaminated sites at the NTS.

Surface and groundwater monitoring conducted by the DTRA and the National Laboratories within testing areas.

Monitoring conducted by Yucca Mountain Project at the southwestern edge of the NTS.

Water-level monitoring conducted throughout southern Nevada by the USGS.

Public outreach (CTLP) monitoring

Oversight monitoring

Numerous research projects conducted by universities and other institutions.

The DOE/NV has initiated action to begin the integration on environmental monitoring at the NTS by preparing this RREMP, which integrates routine environmental radiological monitoring activities. In subsequent efforts, the DOE/NV will look to expanding the concept of centralized data repositories with links to related databases and will work toward standardizing field sample collection, analysis, and validation procedures, so that comparable environmental data from different projects can be shared.

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